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TRANSACTIONS of the
ILLINOIS STATE ACADEMY OF SCIENCE

Volume 87, Numbers 1 and 2 1994

ILLINOIS STATE ACADEMY OF SCIENCE
Founded 1907

Affiliated with the
ILLINOIS STATE MUSEUM, Springfield

ISSN 0019-2252
PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

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Transactions of the Illinois State Academy of Science
(1994), Volume 87, 1 and 2, pp. 1 - 8

Hereditary Variation in *Collinsia concolor*

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ABSTRACT

Five gene loci of *Collinsia concolor* Greene have been identified. (1) The *F* locus, controlling the formation of white markings of cotyledons and leaves, has multiple alleles: *f*, produces no markings; F^p, produces few small dots; F^s, produces numerous large spots; F^{pR} and F^{sR} produce small and large red-tinged and/or red-rimmed white dots respectively. (2) Dominant gene *Ld* controls the formation of maroon dots on cotyledons and leaves. (3) Dominant gene *R* controls the development of the reddish-marron midrib of leaves. (4) Semidominant gene *D* controls the dissection of leaf blade. (5) Dominant gene *Ch* controls the formation of hairs on the outer surface of calyx. Floral variants, whose mode of inheritance has not been fully established, include (1) maroon markings (ring, dots, crossline) of the upper lip, (2) violet tipped upper lip, (3) folded upper lip, (4) hairy keel, (5) restricted gland distribution, and (6) glandless.

INTRODUCTION

Rasmuson (1920) was the first investigator of genetic variability and interspecific crossability of *Collinsia* Nutt. (Scrophulariaceae), a native North American genus of 21 species (Abrams 1951). Hiorth (1930, 1934a, b) established the genetic basis for 12 characters of *C. bicolor* (synonym for *C. heterophylla*), and analyzed interspecific hybrids between *C. bicolor* and *C. bartsiaefolia*. Garber (1956) reported the diploid chromosome number for *C. concolor* to be 14. The first interspecific hybridizations involving *C. concolor* were performed by Garber and Gorsic (1956).

The work, reported in this article, was done at the University of Chicago, and was undertaken with an intention to acquire data for the studies of gene homologies and speciation patterns in the genus *Collinsia*.

MATERIALS AND METHODS

The center of natural distribution of *C. concolor*, an insect pollinated species, is the coastal mountains between San Bernardino County and the northern Lower California. Seed of *C. concolor*, used in this investigation, was collected in the vicinity of Sage, south-western Riverside County, California.

Seeds were germinated on moist filter paper in Petri dishes, kept in refrigerator at 10°-15° C for seven days. Germinated seeds were planted directly into 3.5 inch clay pots filled with sandy loam soil (one to two seeds per pot). Eleven hours of light per day for the first six weeks was sufficient. A subsequent raise to 14 hours of light per day promoted flowering if accompanied by an increase in temperature to 25°- 30° C during the light period. Under these conditions, staked plants developed flower buds within 60-70 days.

Removal of anthers (using forceps) from plants, chosen to be used as the maternal parents in crosses, was performed when the upper lip of flowers began to rise. Five days after emasculation the flowers were fully open, and the stigma was dusted with pollen, which has been collected on the brush-like tip of a rolled piece of torn paper toweling. Forty-eight hours after a successful pollination, the corolla wilted and was usually shed. Ripe seeds, collected from spontaneously opened capsules, may be put to germination without delay to start a new crop. Seeds remain viable for 6 to 7 years.

RESULTS

Five gene loci - one of them having multiple alleles - have been identified. The names of characters and the analytical data of hybridization experiments are given in Table 1.

Dotted (F^p) and Spotted (F^s)

In *C. concolor* the *F* locus, controlling formation of the white markings on the upper surface of cotyledons and leaves, showed the same mode of inheritance as the *F* locus in *C. heterophylla*, a closely related species (Gorsic 1957, Hiorth 1930, 1931).

Plants homozygous for dotted (F^p/F^p) produced few small, transient white dots on the cotyledons and leaves (Fig. 1A), whereas plants homozygous for spotted (F^s/F^s) had numerous, large white spots that were recognizable as long as cotyledons and leaves remained green.

Crosses between plants having no white markings (*f/f*) and dotted (F^p/F^p) or spotted (F^s/F^s) plants produced offspring having few small white dots on the cotyledons and leaves. Both hybrids, F^p/f and F^s/f, produced in the F_2 dotted or spotted and pure green plants in 3 : 1 ratios (Table 1).

The distinctness of the F^p and F^s alleles was further supported by the segregational data of the cultures in which the *R* (red-veined, see below) gene was coupled with the F^p allele, and the *Ld* (dark-dotted, see below) gene was coupled with the F^s allele. A cross between an F^pRld/F^pRld and an F^srLd/F^srLd plant produced trihybrid plants (F^pRld/F^srLd) having on the cotyledons and leaves small white dots and maroon dots, and a red vein on their leaves. Plants of the F_2 progenies of these trihybrids having no red vein on the leaves (F^srLd/F^srLd) exhibited large white spots and pronounced maroon dots, whereas plants exhibiting the red vein, F^pRld/F^srLd and F^pRld/F^pRld, had few small white dots (the latter could be distinguished from the former only by the absence of maroon dots).

Red-tinged (F^{pR}, F^{sR})

The white dots on cotyledons and leaves of *C. concolor* were pure white (F^{p}, F^{s}) or red-tinged (F^{pR}, F^{sR}) with the red pigment concentrated especially around the edges forming red-rimmed whitish dots. A cross between a plant with large red-tinged spots (F^{sR}/F^{sR}) and a pure green (*f/f*) plant produced F_1 plants having small red-tinged spots. The F_2 progeny of this hybrid (F^{sR}/f) segregated in red-tinged spotted and pure green plants in a ratio of 3 : 1 (Table 1). The F_2 progeny of the F^{pR}/F^{s} hybrid with small red-tinged dots segregated for plants having small red-tinged dots and plants with large pure white spots in a 3 : 1 ratio (Table 1).

The genetic uniformity of the F_1s and the F_2 segregation ratios of four hybrids, involving the *F* locus (listed in Table 1), clearly suggest that the *f*, F^{p}, F^{s}, F^{pR} and F^{sR} are members of the same multiple allelic series.

The complete and incomplete white veins on the cotyledons and leaves of *C. concolor* were less clearly expressed as the white veins (F^{v}, F^{i}, F^{z}) of the cotyledons and/or leaves of *C. heterophylla* (Gorsic 1957). The mode of inheritance of the white veins in *C. concolor* has not been pursued.

Dark-dotted (*Ld*) and Red-veined (*R*)

Plants with the dark-dotted (*Ld*) phenotype exhibited transient maroon dots on the cotyledons and leaves. In plants with the red-veined (*R*) phenotype the basal part of the midrib of leaves was reddish-maroon rather than green. The F_2 progenies of both hybrids, *Ld/ld* and *R/r*, segregated in typical monohybrid ratios (Table 1). The *Ld* and *R* genes were completely linked with the *F* locus (Table 2). The *Ld* was found only in the coupling phase with the F^{s} and F^{sR}, but the *R* was observed in both the coupling and repulsion phase with the F^{p}.

Dissected leaf (*D*)

C. concolor has an opposite (decussate) leaf arrangement. The leaf blades of the experimental plants were either entire or lobed (dissected). The lobed leaves exhibited a barely recognizable, a shallow, or a deep cut on one or both sides of the blade, or a pair of basal primary lobes without any secondary lobing (Fig. 1A). The lobing was expressed in leaves of the lowermost one to three (rarely four to five) nodes.

Crosses between plants having leaves with a pair of primary lobes (*D/D*) and plants having entire leaves (*d/d*) produced offspring with variably lobed leaves. The F_2 progenies segregated in 3 : 1 ratios for plants having a pair of primary lobes or variably lobed leaves and plants with entire leaves (Table 1). The dissected leaf (*D*) behaved as a semidominant trait with variable expressivity.

Floral characters

Flowers of *C. concolor* are borne single in the axil of bracts arranged in whorls of two to five on the peduncle. Corolla is 1-1.4 cm long, pentamerous and bilabiate, having a two-lobed upper lip and a three-lobed lower lip. The middle lobe of the lower lip is folded into a keel, which harbors four nonspurred, slightly didynamous stamens and a two-carpellate pistil. The ovary contains 20-25 ovules yielding 15-20 seeds when ripe.

By comparison with the flowers of *C. heterophylla*, the flowers of the experimental plants of *C. concolor* were relatively uniform in morphology and coloration. The upper lip was white to pinkish and, in some plants, violet tipped. Between the cleft of the upper lip and the mouth of corolla tube the following maroon features were observed (Fig. 1B-C): a ring (*Ur*), a group of dots (*Ud*), and a crossline of disjoined dots (*Uc*). The mode of inheritance of these features has not been determined, although it should be pointed out that similar traits are inherited as monogenic dominant characters in *C. heterophylla* (Gorsic 1957).

The lateral lobes of the lower lip were violet with or without a distinctive midvein (veinless). The inheritance of the midveinless in *C. concolor* has not been investigated, but in *C. heterophylla* the veinless (*ll*) was established as a monogenic recessive trait (Hiorth 1930).

Three additional floral variants were observed but not fully investigated: (1) variegated flower, whose lateral lobes of the lower lip were violet-carnea sectored, (2) folded upper lip, whose upper lip lobes were vertically folded backward (Fig. 1B), and (3) hairy keel, whose middle lobe of the lower lip was hairy at the external distal end.

Hairy calyx (*Ch*)

The hairiness of the outer surface of calyx was established as a monogenic dominant trait (Table 1). A similar dominant gene *Ch* is known to control the formation of hairs on the calyx in *C. heterophylla* (Gorsic 1957).

Plants of *C. concolor*, grown for this investigation, exhibited two patterns of glandular hair distribution: (1) glands present on the keel of flowers, the inner and outer surfaces of calyx, and the pedicel, and (2) glands present on the keel, calyx, pedicel, and the peduncle. The mode of inheritance of these two gland distribution patterns in *C. concolor* has not been investigated, but the same two patterns in *C. heterophylla* are known to be controlled by two alleles: *gl*, producing glands on floral parts (as in type 1 above), and gl^2 producing glands on floral parts and peduncle (Gorsic 1957). A dominant gland inhibitor (like *Gi* gene in *C. heterophylla*, Gorsic 1957) is suspect to operate in *C. concolor* as well, but it remains to be proven.

DISCUSSION

The progenies of 60 self-pollinated plants of *C. concolor*, grown from seed of the wild collection, yielded a total of 18 variants; whereas the progenies of 70 self-pollinated *C. heterophylla* plants, grown from seed of the wild collection, yielded more than 50 genetic variants. In the wild both species practice cross-pollination by insects. However, in the greenhouse culture, *C. concolor* plants were noticeably more apt to produce seeds by self-pollination than the plants of *C. heterophylla*. The ability to self-fertilize more readily may be a factor restricting, by some degree of inbreeding, the genetic diversity of *C. concolor*.

One of the more complex loci in the genome of *Collinsia* is the *F* locus. Genes of the *F* locus do not interfere with chlorophyll formation; the mesophyll tissue below the white

markings is green. The white features are brought about by the total reflection of light from structurally changed epidermal layer above them (Hiorth 1931).

In addition to the recessive *f* (null) allele, there are four groups of the dominant *F* alleles (Gorsic 1957, Hiorth 1930, 1931): (1) alleles that control the formation of white dottings: F^f, F^p, F^s; (2) alleles controlling the development of white veins: F^a, F^i, F^v, F^z; (3) alleles regulating the formation of both the white dottings and white veins: F^{pv}, F^{sa}, F^{sv}; and (4) alleles that produce red-tinged and red-rimmed white dottings: F^{pR}, F^{sR}. The F^s allele of *C. concolor*, reported in this article, and F^s allele of *C. heterophylla* (Hiorth 1931) both produce white spots on cotyledons and leaves, but the spots in *C. concolor* appear larger. The F^{pR} and F^{sR} alleles, first reported here, were observed in *C. heterophylla* and *C. tinctoria* as well.

Whether the *F* locus comprises a true multiple allelic series or a group of very tightly linked genes (for dots, veins, pigmentation), cannot be answered at this time; no decisive evidence of recombination between the subunits (genes) of any double superscript *F* alleles (F^{pv}, F^{sa}, F^{pR}, etc.) is available.

The *F* locus is a member of the closely linked *F-R-Ld* gene cluster, whose gene order is not yet fully established. In *C. heterophylla* the *F* and *R* loci are 0.1 crossing-over unit apart (Hiorth 1930), and the recombination between *R* and *Ld* is ca 1.8 percent (Gorsic 1957).

Both F^p or F^s and *Ld* or *R* may be expressed in the same plant; therefore, the dots and spots are not white because of the lack of anthocyanin in cotyledons and leaves (*Ld* and *R* being genetic markers for anthocyanin). The F^p and F^s alleles may be looked upon (1) as the products of recombination by crossing-over between completely linked genes (pseudoalleles) F^{pR} and f^{pr} resulting in F^{pr} (=F^p) and f^{pR}, and recombination between F^{sR} and f^{sr} resulting in F^{sr} (=F^s) and f^{sR} respectively (f^{pr} and f^{sr} being null activity elements, f^{pR} and f^{sR} being ancient dark-dotted genes), or (2) the F^p and F^s may be considered the degenerate F^{pR} and F^{sR} genes, whose pigment regulating function has been completely eliminated by a mutation or by an insertion or removal of controlling elements affecting the *R*-segment of the F^{pR} and F^{sR} genes.

On the other hand, today's F^R (F^{pR}, F^{sR}) alleles may have been derived by the reverse process from revertant F^{pr} and F^{sr} genes in which the pigment producing function of the *r*-segment has been partly or completely restored by similar chromosomal changes described for the anthocyanin marker *R* in corn (Kermicle 1980). Another possible origin of F^R genes could be the f^{pR} and f^{sR} alleles in which the mutation or transposition of controlling elements affected the spotting *p*- and *s*-segments of the f^R genes.

ACKNOWLEDGEMENTS

The author is indebted to the Department of Botany, The University of Chicago, for assistance received through award of the Wychwood and John M. Coulter Research Fellowships, and to Dr. Edward D. Garber for provision of seeds of *C. concolor*. The help received from Mr. Ben C. Driver and Mr. Robert W. Wadsworth is gratefully acknowledged.

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Table 1. The F_2 phenotypic segregation[a] of characters in *Collinsia concolor*.

Character and Symbol	Genotye	No.of domin.	No. of reces.	Total	Chi-Sq.	P
		Cotyledon and leaf characters				
Dotted, F^p	F^p/f	32	12	44	0.031	.8
Spotted, F^s	F^s/f	87	37	124	1.548	.2
Red-tinged, F^R	F^sR/f	52	13	65	0.867	.4
	F^pR/F^s	26	9	35	0.000	–
Dark-dotted, *Ld*	*Ld/ld*	139	49	188	0.063	.8
		Leaf characters				
Red-veined, *R*	*R/r*	74	20	94	0.695	.3
Dissected, *D*	*D/d*	166	70	236	2.734	.1
		Floral characters				
Hairy calyx, *Ch*	*Ch/ch*	30	9	39	0.008	.9

[a] - Expected ratio 3:1

Table 2. Pairs of genes deviating significantly from independent segregation ratio of 9:3:3:1.

Gene pairs	Segregation	AB	Ab	aB	ab	Total
F^s/f *R/r*	F_2	29	–	–	9	38
F^s/f *Ld/ld*	F_2	81	–	–	23	104
Ld/ld R/r	F_2	29	–	–	9	38

Figure 1. Hereditary variants of *Collinsia concolor*.
A. Dotted cotyledons and leaves (*F*^{p}); Dissected leaves (*D*).
B. Maroon markings on the upper lip: Ring (*Ur*), Dotts (*Ud*), Crossline (*Uc*); Folded upper lip.
C. Upper lip without Ring.

Transactions of the Illinois State Academy of Science
(1994), Volume 87, 1 and 2, pp. 9 - 27

Spatial and Temporal Variation of Diatom Community Structure in Two East-Central Illinois Streams

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ABSTRACT

Much attention has been given to macroinvertebrate and fish communities of the Embarras River Basin. In contrast, algal communities have been ignored, even though algae are potentially more sensitive as monitors of environmental change. Recent industrialization in the watershed could negatively impact water quality of the Embarras River and Brushy Fork - streams already subject to agricultural runoff, wastewater plant effluent, and landfill leachate. Our purpose was to describe attached diatom communities in order to establish a baseline for future comparisons. Artificial substrates were deployed in the Embarras River and in Brushy Fork for successive two-week intervals from 30 May 1990 through 22 September 1990. While seventy species of diatoms were identified, seventy to ninety-nine percent of all communities were comprised of only eleven species. These dominant species are recommended as potential biological monitors, while community level parameters such as species richness, diversity, and evenness are believed to be insensitive to environmental perturbation.
Key Words: stream ecology, periphyton, algae, diatoms, biological monitoring

INTRODUCTION

The degradation of streams worldwide is partially the result of industrialization, energy production, modern agricultural practices, land development and deforestation. These activities generally increase burdens of heavy metals, pesticides, herbicides, industrial chemicals, and sediment in aquatic systems. Such perturbations often produce streams and lakes which are low in productivity and species diversity (Takamura et. al., 1989), and which have reduced economic and aesthetic value.

Techniques have been developed for utilizing organisms to monitor the effects of environmental perturbations on aquatic ecosystems. Methods of biological assessment range from floristic and faunistic studies to complex community analyses and lengthy *in situ* bioassays (Friant and Koerner, 1981). Use of specific organisms in natural communities as indicators of pollution was proposed as early as 1913 (Wilhmin, 1975). Algae and aquatic macrophytes are especially useful as biomonitors because they vary in their sensitivities to pollutants (Friant and Koerner, 1981; Bailey and Stokes, 1985;

Smith and Kwan, 1989). Diatom communities on artificial substrates are one of the more widely used biomonitors in the United States (Whitton, 1975).

The Embarras River receives largely agricultural runoff along with municipal and industrial waste effluents, as well as other miscellaneous urban and highway runoff. Continued industrialization, including the citing of a heavy metal recycling facility near Newman, IL, could potentially impact aquatic communities in Brushy Fork and the Embarras River. In 1987 the Illinois Environmental Protection Agency conducted an intensive study of the Embarras River basin in effort to ascertain the condition of the various reaches of the river (Ettinger, 1989). While data were obtained on macroinvertebrate and fish community structures, no data were collected on algal communities. Therefore, this study was initiated to obtain baseline data on the community structure of attached algae (periphyton), specifically that of diatoms.

MATERIALS AND METHODS

Study Site

The Embarras River originates south of Champaign, Illinois (Fig. 1) and flows approximately 310 km to its confluence with the Wabash River near Vincennes, Indiana. The Embarras drains an area of approximately 4500 km^2 in eleven east-central Illinois counties (Ettinger, 1989). Brushy Fork, a tributary of the Embarras, originates northeast of Newman, Illinois and enters the Embarras in Douglas County. Preliminary field investigations and studies of United States Geological Survey topographic maps led to the selection of four sample sites (Fig. 1). Site selection was based on two criteria: i) ease of access to the site (i.e., sites selected were located near roadway bridges) and ii) proximity to the mouths of Brushy Fork and Newman Drain #2. Sampling sites were established in the Embarras River 4.7 km downstream (DNEMB) and 3.7 km upstream (UPEMB) of the mouth of Brushy Fork, and in Brushy Fork 3.0 km upstream (UPBFK) and 1.1 km downstream (DNBFK) of the mouth of Newman Drain #2 (Fig. 1).

Sampling Regime

Artificial substrates were continuously exposed for 2-week intervals from 30 May 1990 to 22 September 1990. Substrates (35.5 cm X 24.4 cm plexiglas sheets) were attached to flotation devices consisting of styrofoam blocks attached at either end of a 71 cm X 15 cm X 1.5 cm PVC pipe frame. Floats were anchored to cement blocks with ample rope to compensate for depth fluctuations. Substrates were recovered at the end of each sampling interval and replaced with clean substrates. Stream flow, conductivity, dissolved oxygen, pH, and temperature were determined on each sample collection date.

Laboratory Analyses

Air-dried periphyton (i.e., primarily diatoms, but also including other algae, insect larvae, invertebrate eggs, and trapped sediment) was removed from a 185 cm^2 area of the upper surface of each substrate and placed into separate, acid-washed, preweighed glass vials. Samples were dried for 24 hours in a convection oven at 103-105 °C, cooled in a desiccator and weighed to the nearest 0.1 mg. Net mass of the periphyton was determined by subtraction of tare mass.

Approximately 60 ± 0.1 mg of each periphyton sample were digested in clean Pyrex centrifuge tubes with 1 mL of concentrated sulfuric acid and a few crystals of potassium dichromate (Patrick and Reimer, 1966). Digestion was continued for a 48-hr period, during which samples were agitated occasionally with subsequent rinsing of centrifuge tube walls with deionized water. After digestion, tubes were filled to 10 mL, shaken vigorously to suspend the digested material and centrifuged at 1,750 revolutions min^{-1} for 10 minutes. Following aspiration of the supernatant, tubes were again filled to 10 mL, shaken and centrifuged. This rinsing procedure was repeated a third time to insure removal of all acid and tubes were filled to 10 mL in preparation for mounting. Dilutions of 1:2, 1:5 and 1:10 were prepared from the original suspension. Fifty µL of the original suspension and of each dilution were evenly distributed on separate circular (d = 1.2 cm) coverslips and dried on a hot plate. Coverslips were inverted and mounted on a glass microscope slide using Permount.

Coverslips were scanned at 1000x using a Bausch and Lomb phase-contrast microscope equipped with a Whipple grid and the number of each species observed in each scan was recorded. Species were identified according to Wolle (1894), Tiffany and Britton (1952), Patrick and Reimer (1966, 1975) and Dodd (1987). Diatom frustules were counted if they were at least half intact and if they i) were completely contained within the optical grid but did not touch or extend past the bottom line of the grid or, ii) if they touched the top line of the optical grid or extended into the grid from the top. Successive scans were observed until a minimum of 500 frustules had been enumerated. The area of each scan was determined and the total area scanned was recorded. Total and individual species densities were calculated from data on relative abundance as follows:

$$\text{Density (no. cm-2)} = N \frac{(A_t)}{(A_s)} (F_d) (V_o) \frac{(M_t)}{(M_d)} \frac{1}{(A_p)}$$

where:
- N = number of frustules observed,
- A_t = total area of coverslip (cm^2),
- A_s = area scanned (cm^2),
- F_d = dilution factor (mL^{-1}); (200 for 1:10 dilution, 100 for 1:5 dilution, 40 for 1:2 dilution, 20 for no dilution)
- V_o = original volume of suspension (mL),
- M_t = mass scraped from substrates (mg),
- M_d = mass digested (mg),
- A_p = area of plexiglas scraped (cm^2).

Diversity (Shannon and Weaver, 1963) was calculated as:

$$H' = -\sum_{i=1}^{s} p_i(\log p_i)$$

where:
- s = number of species present in a sample,
- p_i = proportion of community represented by species i.

Evenness (J), which is the ratio of observed diversity to maximum diversity (Pielou, 1969), was calculated based on the formula:

$$J = H' / H'_{max}$$

where: H' = observed diversity index,
H'_{max} = maximum diversity, (= log s).

Statistical Analyses

Substrates were not replicated at sampling sites. Therefore, two-way analysis of variance (ANOVA) without replication (Sokal and Rohlf, 1981) was used to determine significant ($p < 0.05$) differences for characteristics of the physical/chemical environment and the diatom community with sample date and site as independent variables. Because observations were not replicated, it was not possible to test for interaction between independent variables. Characteristics which differed significantly between sites or over time were subjected to correlation analysis (Sokal and Rohlf, 1981). For characteristics which did not differ significantly by site, a single factor (sample date) ANOVA was performed utilizing the Scheffé method to identify significant differences between means, with sites as replicates (Sokal and Rohlf, 1981).

RESULTS

The physical and chemical environments of the four sampling sites proved to be quite variable. Dissolved oxygen was the only measured characteristic for which significant differences were not detected, while stream flow, temperature, conductivity, and pH all varied significantly ($p < 0.05$) between sampling sites and over time. Stream flow tended to be higher early in the study period, with a general decline at all four sites through August and September (Fig. 2a). Water temperature increased from May through August before declining again in September (Fig. 2b). Conductivity appeared to decline over the course of the study at all sites except UPBFK (Fig. 3a) and pH was relatively higher in May and September with lower values being observed during mid-summer (Fig. 3b).

Neither diversity nor evenness varied significantly ($p < 0.05$) by date or site, thus overall means ($n = 28$) were calculated and are reported as 0.77 (H') and 0.58 (J). However, variation in diatom density and species richness was significant ($p < 0.05$) for sampling date. Total diatom density appeared to decrease over the course of the study, with significant differences detected between mean diatom densities for sampling periods one and six as well as for periods one and seven (Table 1). No readily discernible trend was apparent for species richness, with only sampling periods two and six differing significantly (Table 1). Significant correlations ($p < 0.05$) were not observed between any environmental variable (stream flow, temperature, conductivity, pH) and either diatom density or species richness.

Seventy different diatom species were identified (Table 2). Major community dominants, i.e., those species which comprised ten percent or more of the total individuals observed on at least one sampling date, accounted for seventy to ninety-nine percent of the total diatom community at all four sites. Dominant species included *Achnanthes lanceolata lanceolata*, *Cocconeis placentula euglypta*, *Cocconeis placentula placentula*, *Cyclotella*

meneghiniana meneghiniana, *Gomphonema angustatum angustatum*, *Gomphonema olivaceum olivaceum*, *Navicula lanceolata lanceolata*, *Navicula seminulum seminulum*, *Navicula subarvensis subarvensis*, *Navicula viridula viridula*, and *Nitszchia amphibia amphibia*.

Four species were regular community dominants throughout the study period (Figs. 4a, 4b, 5a, 5b). *Achnanthes lanceolata lanceolata* was a major constituent of the diatom community at all sites from June through September with peaks in relative abundance generally occurring prior to the end of July. *Cocconeis placentula euglypta* and *C. placentula placentula* generally replaced *A. lanceolata lanceolata* as dominants during August but declined in September. Although *N. seminulum seminulum* was relatively abundant from early June through early September at DNBFK, it was never an important component of the Embarras River and UPBFK communities.

Early season communities were characterized by the presence of three species (Figs. 6a, 6b, 7a, 7b). *Navicula subarvensis subarvensis* was abundant on 13 June at all four sites but was virtually absent in all communities from July through September. While *G. angustatum angustatum* and *G. olivaceum olivaceum* were abundant at UPEMB and DNEMB on 13 June, neither achieved high densities at the Brushy Fork sites. Both species of *Gomphonema* were minor components of Embarras River communities for the remainder of the study period except for a peak in relative abundance observed for *G. angustatum angustatum* on 8 August.

Four species occurred in higher relative abundance later in the study period (Figs. 8a, 8b, 9a, 9b). *Nitzschia amphibia amphibia*, never present in high numbers at UPEMB and a major component of the DNEMB community only on 8 August, was an important component of the Brushy Fork communities during August and September. *Cyclotella meneghiniana meneghiniana* was rare or absent at all four sites through July, and never attained high relative abundance at DNEMB. This typically planktonic species was an important constituent at UPEMB and the Brushy Fork sites on 22 September, at which time it composed eighty-seven percent of all individuals at DNBFK. Relative abundance of *N. lanceolata lanceolata* peaked on 22 September at the Embarras River sites, on 25 August at UPBFK, and on 8 September at DNBFK. *Navicula viridula viridula* was abundant only at UPBFK during September.

DISCUSSION

Our main goal was to provide a basis of comparison for future studies regarding changes in water quality within the Embarras River drainage. One would expect species richness, diversity, and evenness to reflect variation in the physical and chemical characteristics of the Embarras River and Brushy Fork if community level parameters are to serve as indicators of water quality. Seasonal variation in species richness in the Embarras River and Brushy Fork was not remarkable since the only observed significant difference was between means for sampling periods two and six. Krebs (1985) points out that even stable communities are in a constant state of flux, with some species becoming less abundant while others increase in number. Furthermore, diversity and evenness did not vary significantly over time or between sites in spite of the temporal and spatial differences which were observed for stream flow, temperature, conductivity, and pH.

Thus, we concur with Sullivan (1986) and Round (1991) that diversity indices fail as indicators of water quality.

The temporal decline in diatom density which we observed may have resulted directly or indirectly from the general decrease in stream flow over the course of our study, even though a significant correlation was not detected. Douglas (1958) and Jones (1978) observed similar relationships between stream flow and diatom density for communities (including species of *Achnanthes* and *Cocconeis*) occurring on natural substrates in streams. Possible explanations for this observed pattern include depletion of available nutrients at low flow (Douglas, 1958), increased herbivore activity (Jones, 1978), or decreased metabolic activity due to "suffocation" by silt or detritus deposited on the algae (Jones, 1978).

Sullivan (1986) suggested that the identity and autecology of the constituent species are paramount for assessing water quality through use of diatom communities. Diatom species encountered during this investigation possess a variety of ecologies (Patrick and Reimer, 1966; 1975) which are potentially responsible for the fluctuations in community structure that were observed. If diatom communities along with associated abiotic factors are monitored in the same locations for several seasons it could be possible to verify patterns of seasonal succession for these locations and ultimately develop an index for use in identifying the onset of acute or chronic pollution. For example, metal-tolerant species are able to survive in waters enriched with heavy metals while species which are sensitive to heavy metals or other pollutants may be eliminated from the community as a result of toxic conditions (Stokes, 1983).

Information on community structure obtained during this study provides a foundation for further research into the relative sensitivity of diatoms to heavy metals or other pollutants which may be introduced into the Embarras River and Brushy Fork. Laboratory determinations of differential sensitivities of species are required in order to establish a causal relationship between any form of pollution and changes in the diatom community. Furthermore, it will be necessary to establish the relative importance of pollutants versus naturally occurring perturbations (variations in flow, water temperature, etc.) with regard to success of any given species. Research efforts should focus initially on those species which were found to be dominant at different times of year (e.g., *Achnanthes lanceolata lanceolata*, *Cocconeis placentula euglypta*, *Cyclotella meneghiniana meneghiniana*, *Navicula subarvensis subarvensis*) since it is their disappearance which would be most readily detectible in the event of any environmental perturbation.

ACKNOWLEDGEMENTS

The contributions of J. Carlson, C. Mueller, M. Vaultonburg, and W. Weiler are gratefully acknowledged. This work was supported in part by a grant from the Eastern Illinois University Council for Faculty Research.

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Table 1. Mean density (millions per square centimeter) and species richness of diatom communities occurring on artificial substrates from 14 June 1990 through 22 September 1990 in the Embarras River and Brushy Fork. Mean values for exposure periods which differ significantly ($p < .05$) from a given value are shown in parentheses.

Exposure (Period) Date	Density	Species Richness
(1) 5/30-6/13	1.144 (6,7)	22.25
(2) 6/27-7/11	0.557	13.25 (6)
(3) 7/11-7/25	0.487	17.00
(4) 7/25-8/08	0.638	21.75
(5) 8/08-8/25	0.346	17.50
(6) 8/25-9/08	0.153 (1)	26.50 (2)
(7) 9/08-9/22	0.071 (1)	25.00

Table 2. Species of diatoms collected from sites in the Embarras River, upstream (UPEMB) and downstream (DNEMB) of the mouth of Brushy Fork, and in Brushy Fork, upstream (UPBFK) and downstream (DNBFK) of the mouth of Newman Drain #2. The following categories of occurrence at each sampling site are recorded for each species: rare (+), common (++), uncommon dominant (+++), common dominant (++++).

	Sample Collection Site			
Species	UPEMB	DNEMB	UPBFK	DNBFK
Achnanthes exigua var. *heterovalva* Krasske			+	+
Achnanthes hauckiana Grun. var. *hauckiana*			+	+
Achnanthes lanceolata (Breb.) Grun. var. *lanceolata*	++++	++++	++++	++++
Amphora ovalis var. *affinis* (Kuetz.) V.H. ex De T.	+	+	+	+
Amphora ovalis (Kuetz.) Kuetz. var. *ovalis*				+
Amphora perpusilla (Grun.) Grun. var. *perpusilla*	++	++	++	++
Amphora submontana Hust. var. *submontana*	++	++	++	++
Amphora veneta Kuetz. var. *veneta*	+			
Caloneis lagerstedtii Choln. var. *lagerstedtii*	+			
Caloneis lewisii var. *inflata* (Shultze) Patr.		+	+	++
Caloneis ventricosa var. *minuta* (Grun.) Patr.		++		++
Cocconeis pediculus Ehr. var. *pediculus*			+	
Cocconeis placentula var. *euglypta* (Ehr.) Cl.	++++	++++	++++	++++
Cocconeis placentula var. *lineata* (Ehr.)	++	++	++	++
Cocconeis placentula Ehr. var. *placentula*	++++	++++	++++	++++
Cyclotella meneghiniana Kuetz. var. *meneghiniana*	+++	++	++++	++++
Cymatopleura solea (Breb.) W. Sm. var. *solea*	++	+		
Cymbella affinis Kuetz. var. *affinis*	+	++	++	++
Cymbella sinuata Greg. var. *sinuata*				+
Cymbella tumida (Breb. ex Kuetz.) V.H. var *tumida*				+
Diatoma vulgare Bory var. *vulgare*	+	+		
Diploneis oblongella (Nage. ex Kuetz.) *oblongella*			+	++
Fragilaria capucina Desmaz. var. *capucina*	+			
Fragilaria vaucheriae (Kuetz.) Peters. var. *vaucheriae*	+	+		
Gomphonema acuminatum Ehr. var. *acuminatum*	+		++	+
Gomphonema affine Kuetz. var. *affine*	++	++	++	
Gomphonema angustatum (Kuetz.) Rabh. var. *angustatum*	++	+++	++	++
Gomphonema olivaceum (Lyngb.) Kuetz. var. *olivaceum*	+++	+++	++	++
Gomphonema truncatum Ehr. var. *truncatum*			+	
Gyrosigma acuminatum (Kuetz.) Rabh. var. *acuminatum*	++	++	++	++
Hantschia amphioxys (Ehr.) Grun. var. *amphioxys*		+	++	+
Melosira varians C.A. Ag. var. *varians*	+	++	++	++
Meridion circulare (Grev.) Ag. var. *circulare*	+	+		
Navicula capitata Ehr. var. *capitata*	+	++	++	++
Navicula circumtexta Meist. ex Hust. var. *circumtexta*		+		
Navicula cuspidata (Kuetz.) Kuetz. var. *cuspidata*	+		++	++
Navicula decussis Oestr. var. *decussis*	+	+		+
Navicula exigua Greg. ex Frun. var. *exigua*	++	++	++	++
Navicula fluens Hust. var. *fluens*	++	++	++	++

Table 2. (continued)

Species	Sample Collection Site UPEMB	DNEMB	UPBFK	DNBFK
Navicula gysingensis Foged var. *gysingensis*		+		
Navicula lanceolata (Ag.) Kuetz. var. *lanceolata*	++++	++++	+++	+++
Navicula placentula (Ehr.) Kuetz. var. *placentula* **	+	+		
Navicula pupula var. *elliptica* Hust.	+	+		
Navicula pupula var. *mutata* (Krasske) Hust. **	+			
Navicula pupula Kuetz. var. *pupula*	+		++	+
Navicula pygmaea Kuetz. var. *pygmaea*			+	
Navicula seminulum Grun. var. *seminulum*	++	++	++	++++
Navicula subarvensis Hust. var. *subarvensis*	+++	+++	+++	+++
Navicula tenera Hust. var. *tenera*	++	++	++	
Navicula viridula (Kuetz.) Kuetz. emend. V.H. var. *viridula*	++	++	++++	++
Neidium dubium f. *constrictum* Hust. **	++	++	+	
Nitzschia acicularis (Kuetz.) W. Sm. var. *acicularis*		+	++	+
Nitzschia amphibia Grun. var. *amphibia*	++	+++	++++	+++
Nitzschia angustata (W. Sm.) Grun. var. *angustata*		+		+
Nitzschia hungarica Grun. var. *hungarica*		++	+	+
Nitzschia intermedia Hantzch var. *intermedia*			+	
Nitzschia tryblionella var. *victoriae* Grun.			+	
Nitzschia umblicata Hust. var. *umblicata*	++		++	
Nitzschia valdestriata Aleem & Hust. var. *valdestriata*	++	++	++	++
Pinnularia abaujensis (Pant.) Ross var. *abaujensis*		+		
Rhoicosphenia curvata (Kuetz.) Grun, var. *curvata*		++	++	
Surirella angusta Kuetz. var. *angusta*		+	+	+
Surirella linearis var. *constricta* Grun.	+			
Surirella ovata var. *crumena* (Breb.) V.H.		+	+	+
Surirella ovata Kuetz. var. *ovata*	++	++	++	++
Surirella ovata var. *pinnata* (W. Sm.) Hust.			+	
Synedra acus Kuetz. var. *acus*		+		
Synedra rumpens var. *meneginiana* Grun.	+	+	+	+
Synedra ulna (Nitz.) Ehr. var. *ulna*	+	+	+	
Tabellaria flocculosa (Roth) Kutz. var. *flocculosa*		+		

(**) - not previously reported in Illinois

(+) - present on one sampling date, but not in significant numbers

(++) - present on more than one sampling date, but never constituting greater than 10% of the total individuals observed

(+++) - comprising greater than 10% of the total individuals in the community on one sampling date

(++++) - comprising greater than 10% of the total individuals in the community on two or more sampling dates

Figure 1. Embarras River and Brushy Fork drainage in Champaign, Edgar and Douglas Counties showing the locations of sampling sites in the Embarras River, upstream (UPEMB) and downstream (DNEMB) of the mouth of Brushy Fork, and in Brushy Fork, upstream (UPBFK) and downstream (DNBFK) of the mouth of Newman Drain #2.

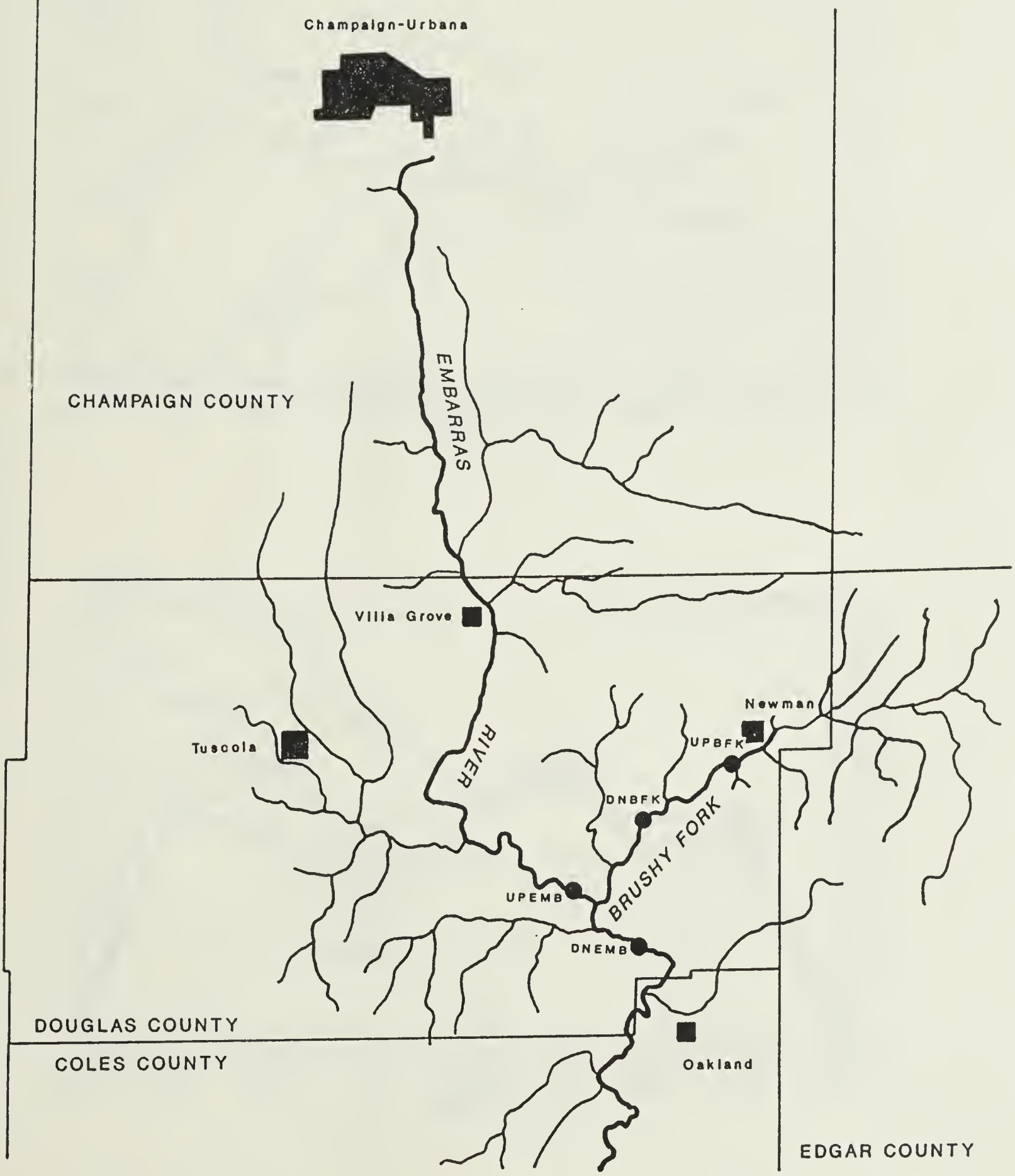


Figure 2. Stream flow (a) and temperature (b) observed at four sites in the Embarras River and Brushy Fork from 13 June 1990 through 22 September 1990.

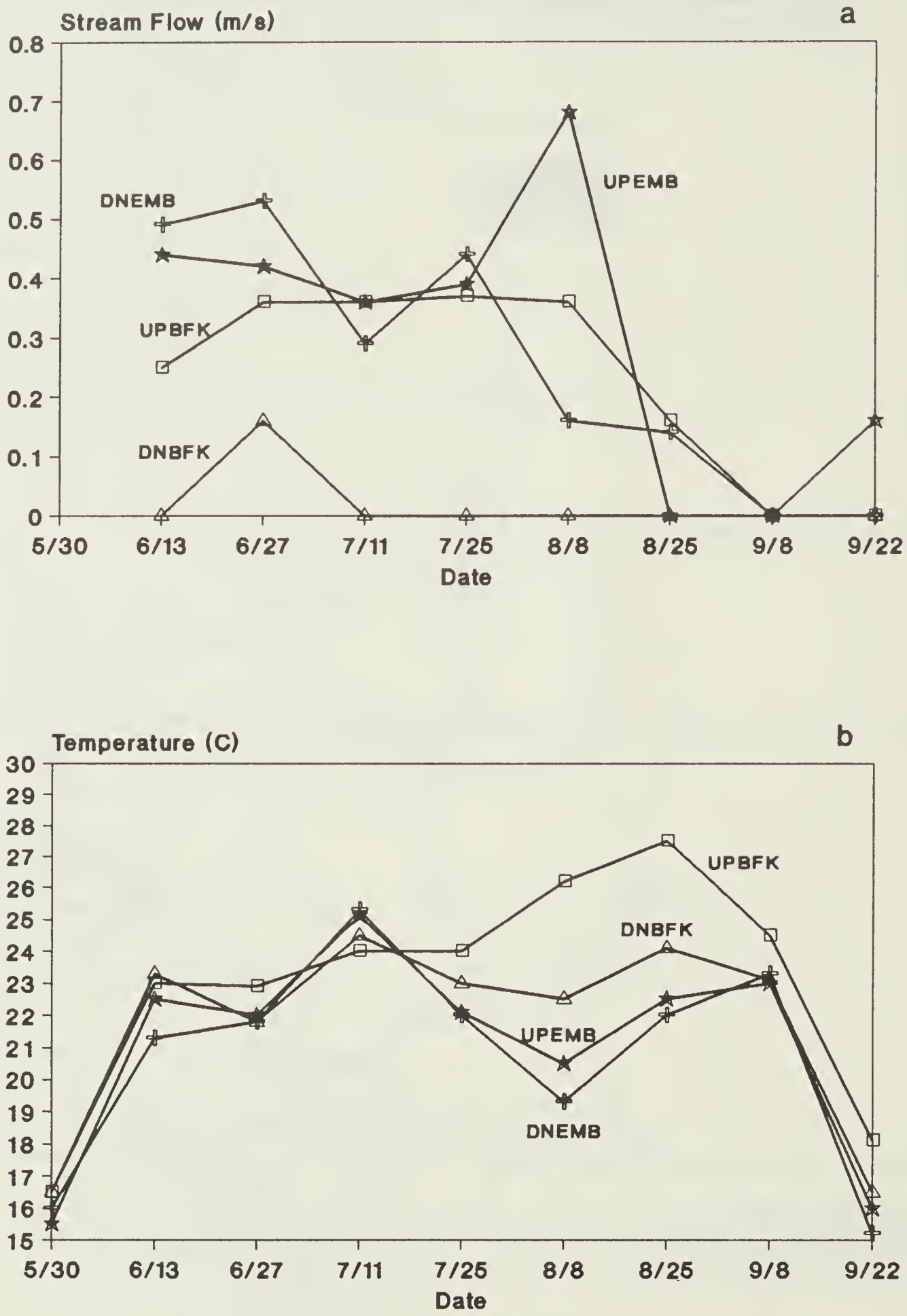
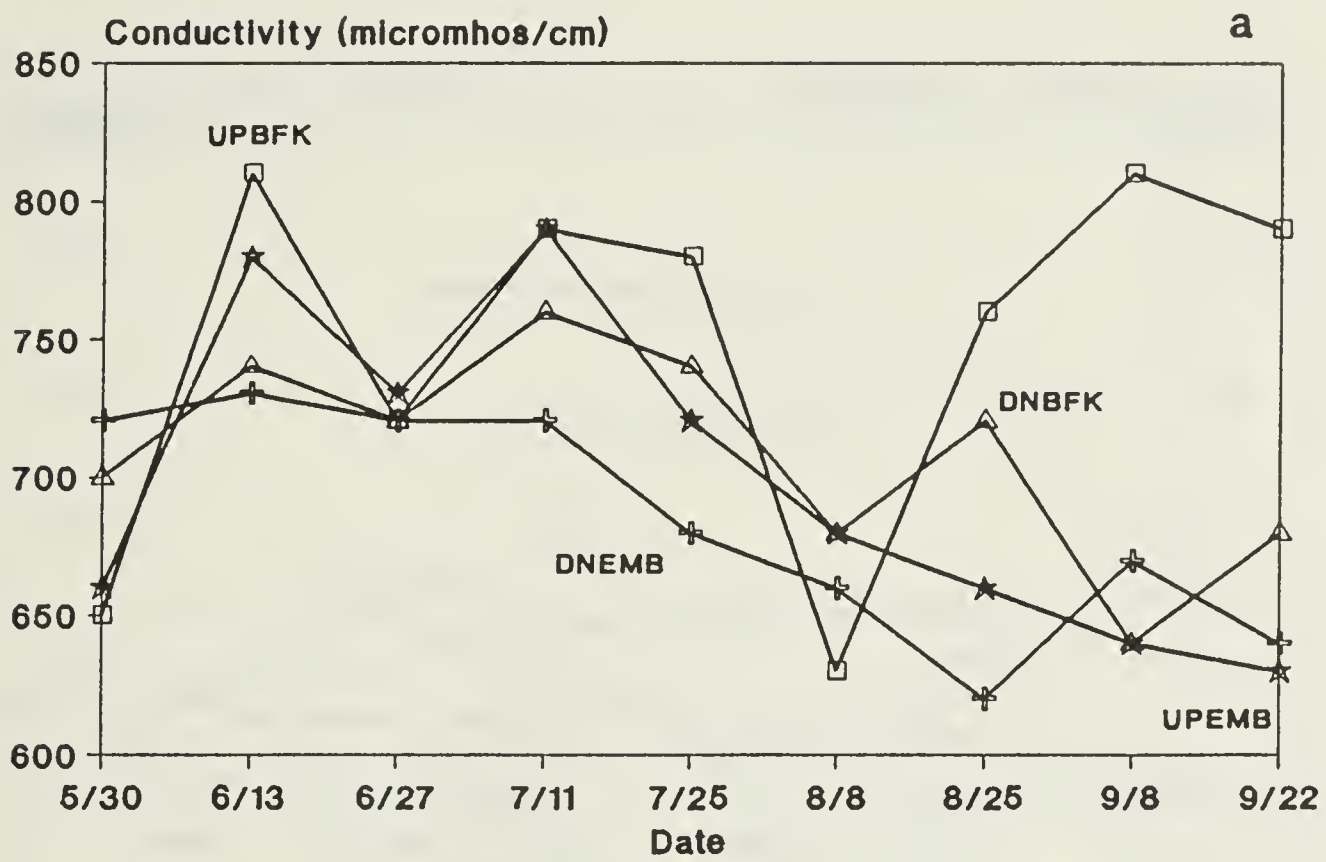


Figure 3. Conductivity (a) and pH (b) observed at four sites in the Embarras River and Brushy Fork from 13 June 1990 through 22 September 1990.



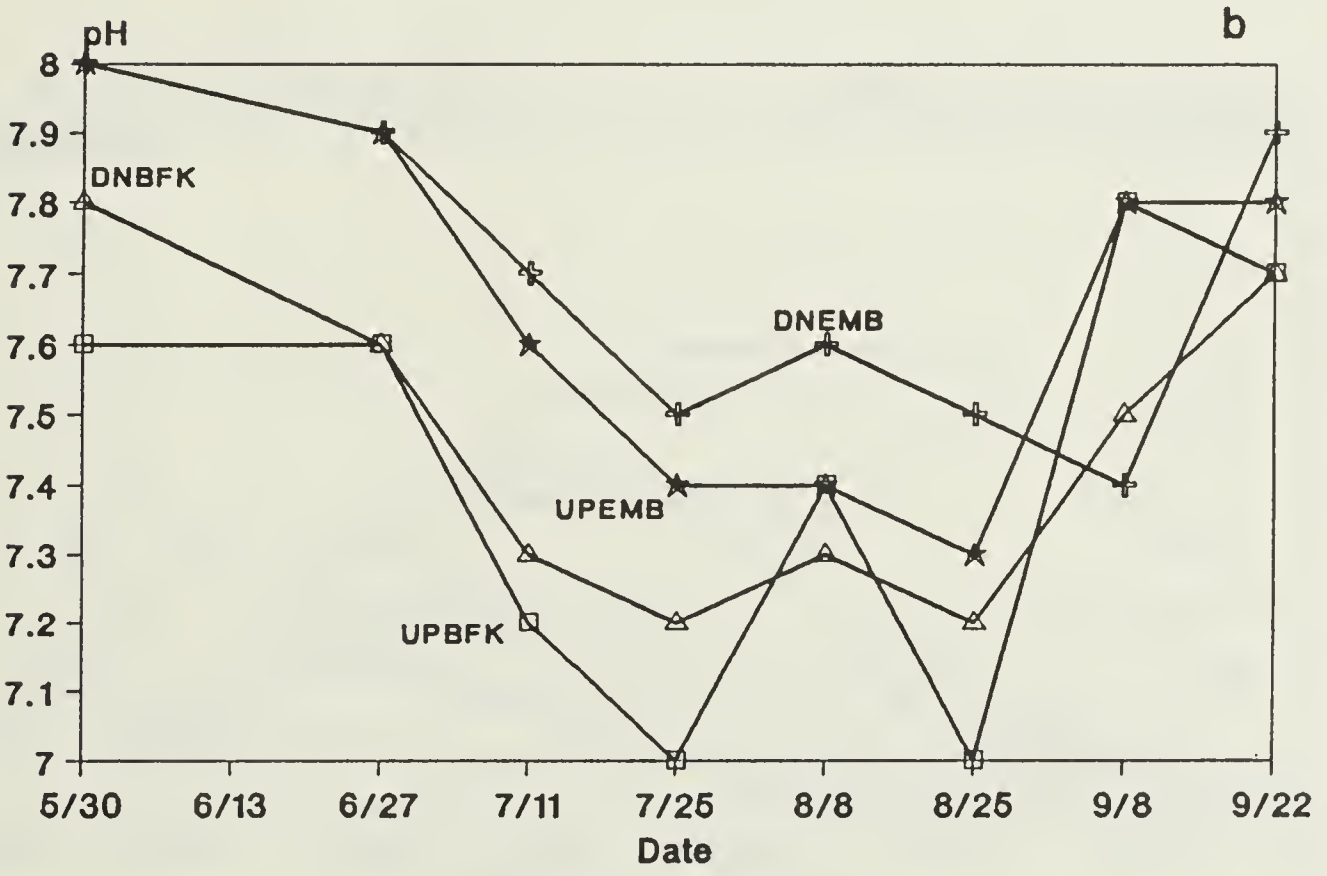
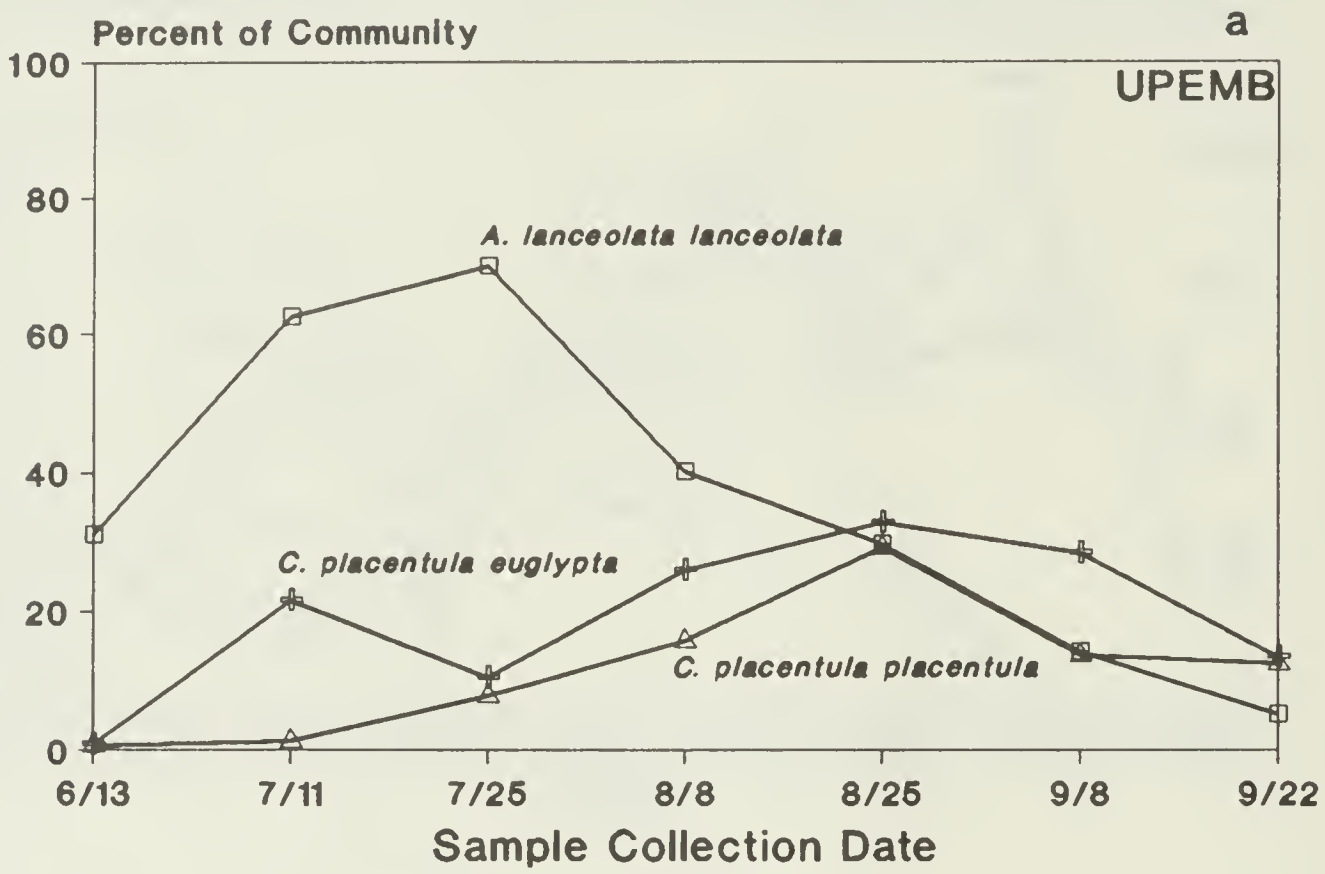


Figure 4. Relative abundance of *A. lanceolata lanceolata, C. placentula euglypta*, and *C. placentula placentula* from 13 June 1990 through 22 September 1990 at UPEMB (a) and DNEMB (b).



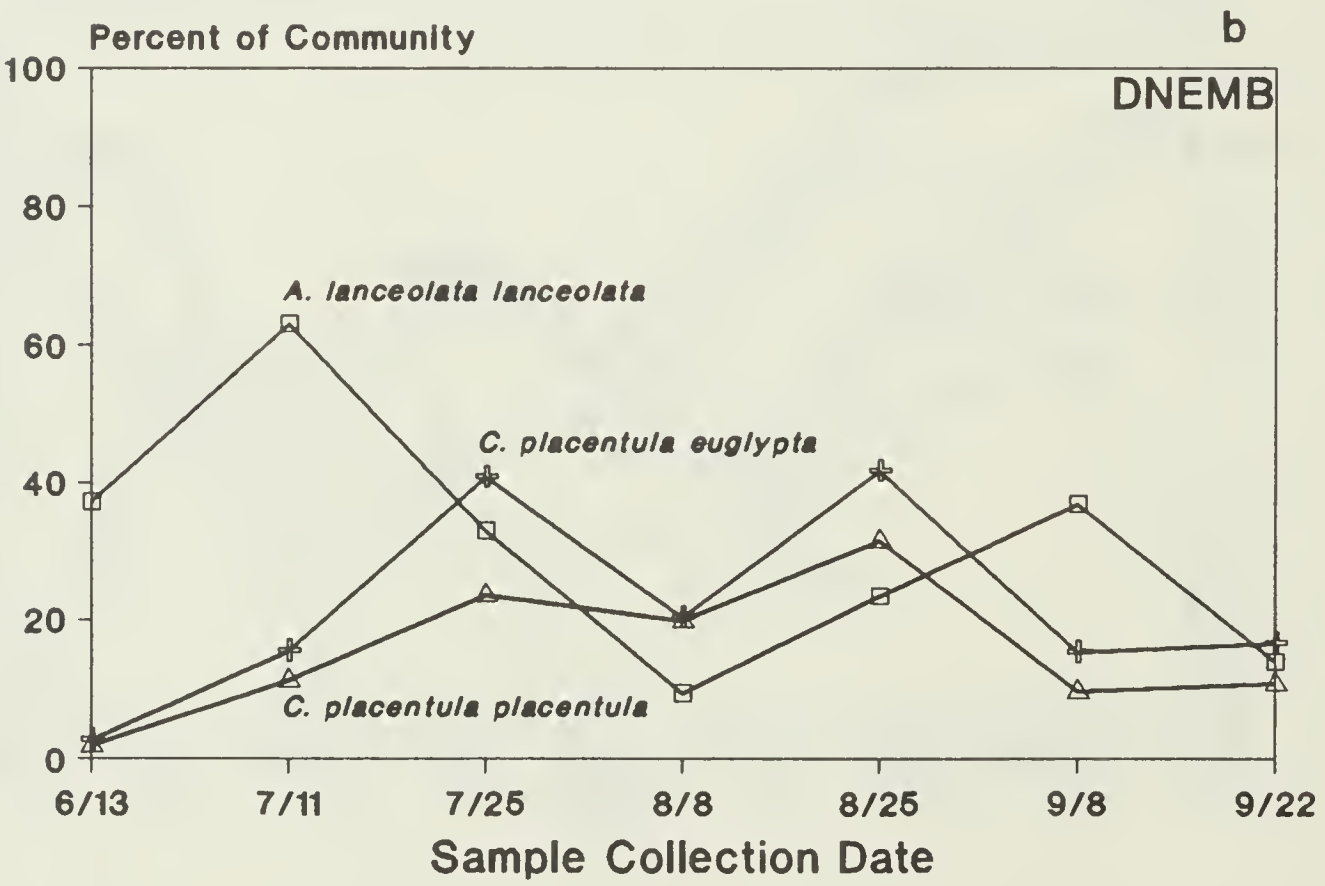
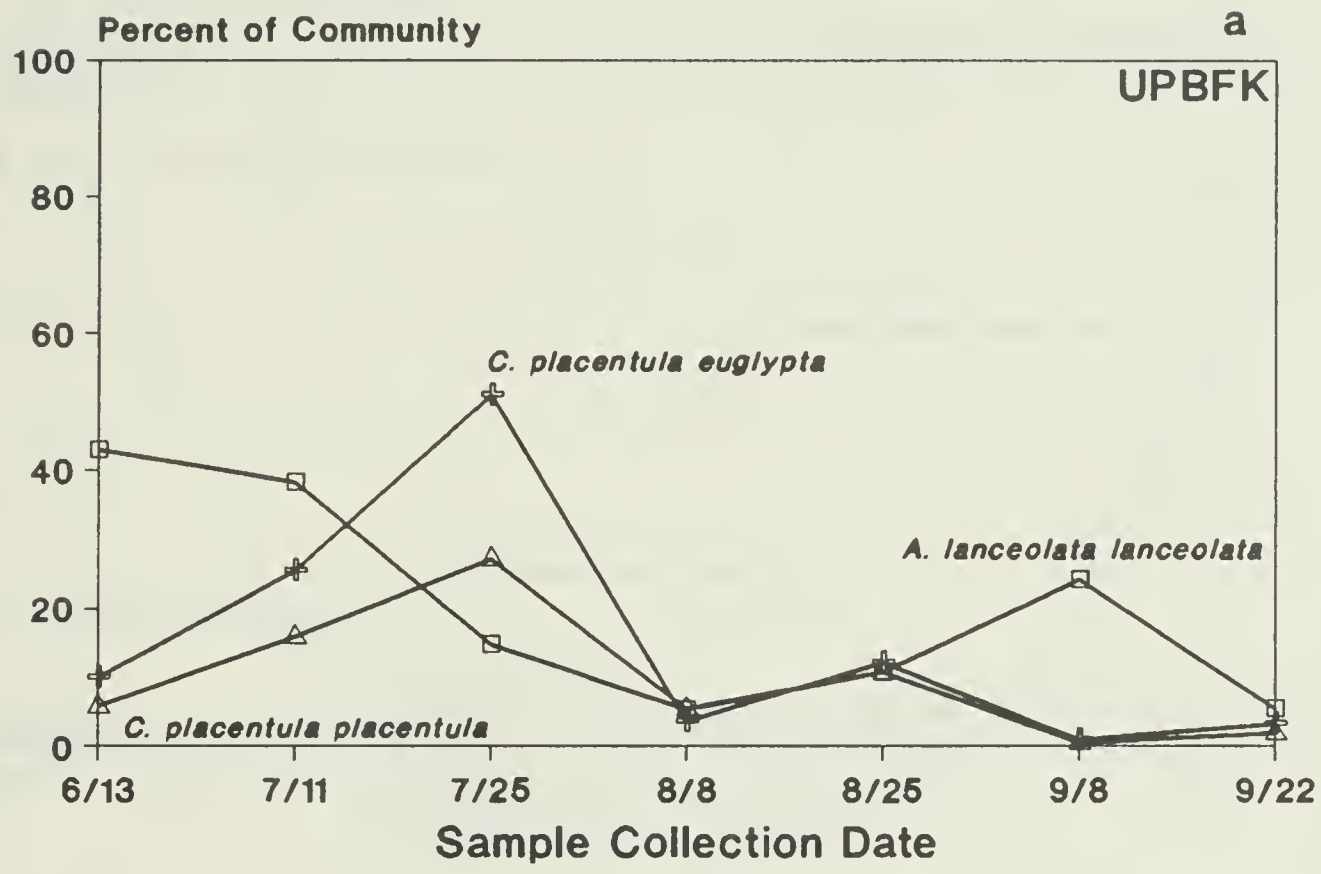


Figure 5. Relative abundance of *A. lanceolata lanceolata, C. placentula eugylpta, C. placentula placentula*, and *N. seminulum seminulum* from 13 June 1990 through 22 September 1990 an UPBFK (a) and DNBFK (b).



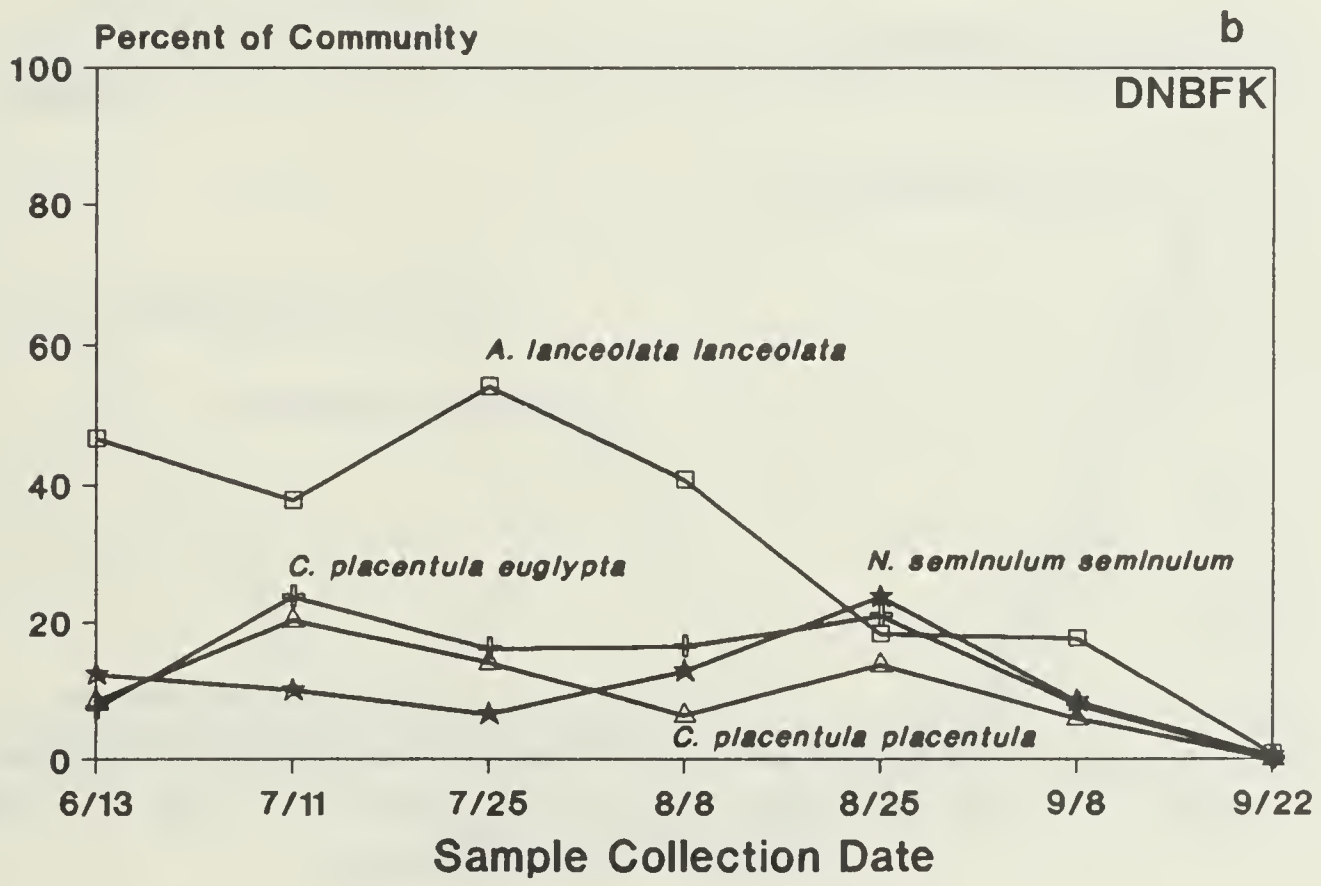
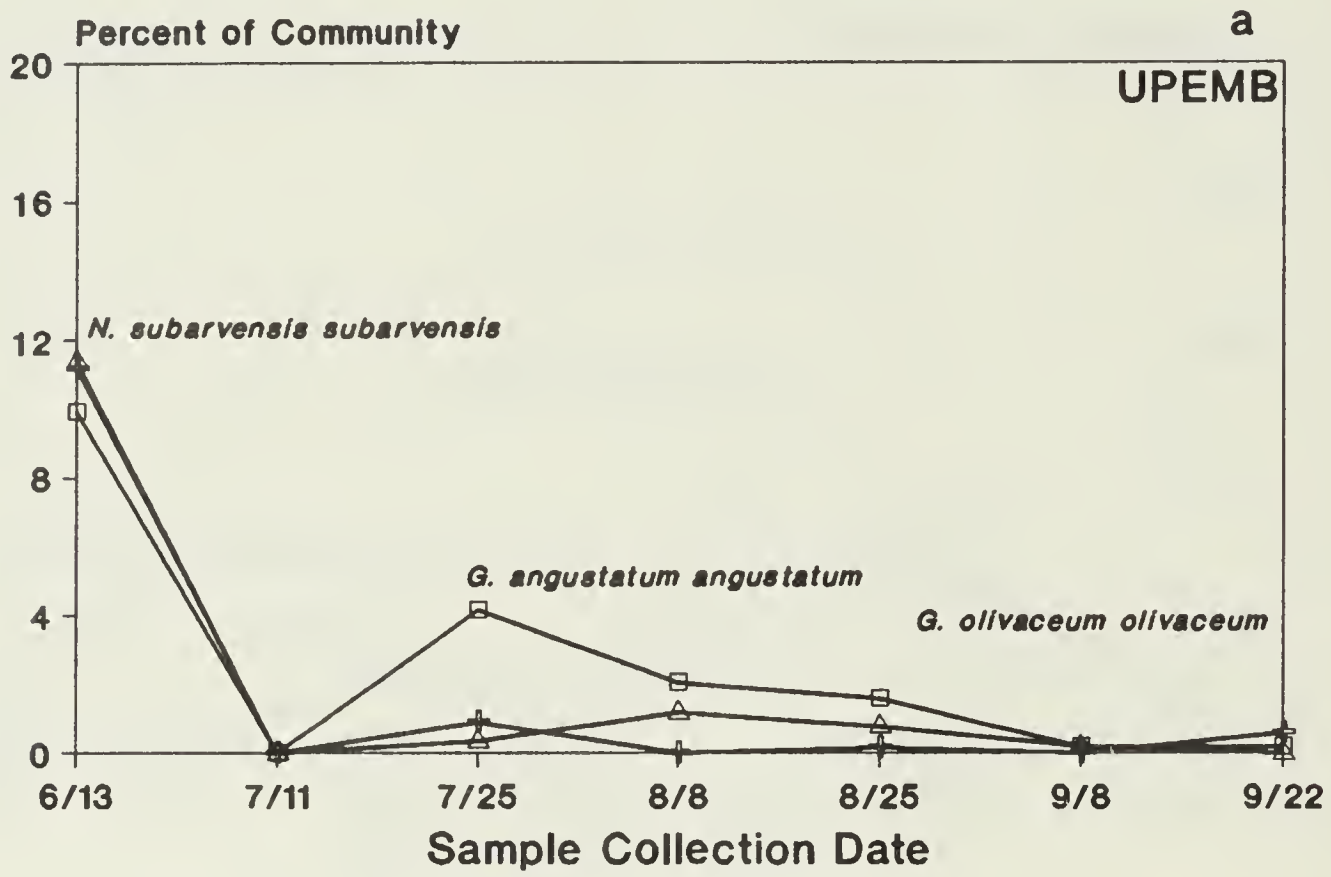


Figure 6. Relative abundance of *G. angustatum angustatum, G. olivaceum olivaceum,* and *N. subarvensis subarvensis* from 13 June 1990 through 22 September 1990 at UPEMB (a) and DNEMB (b).



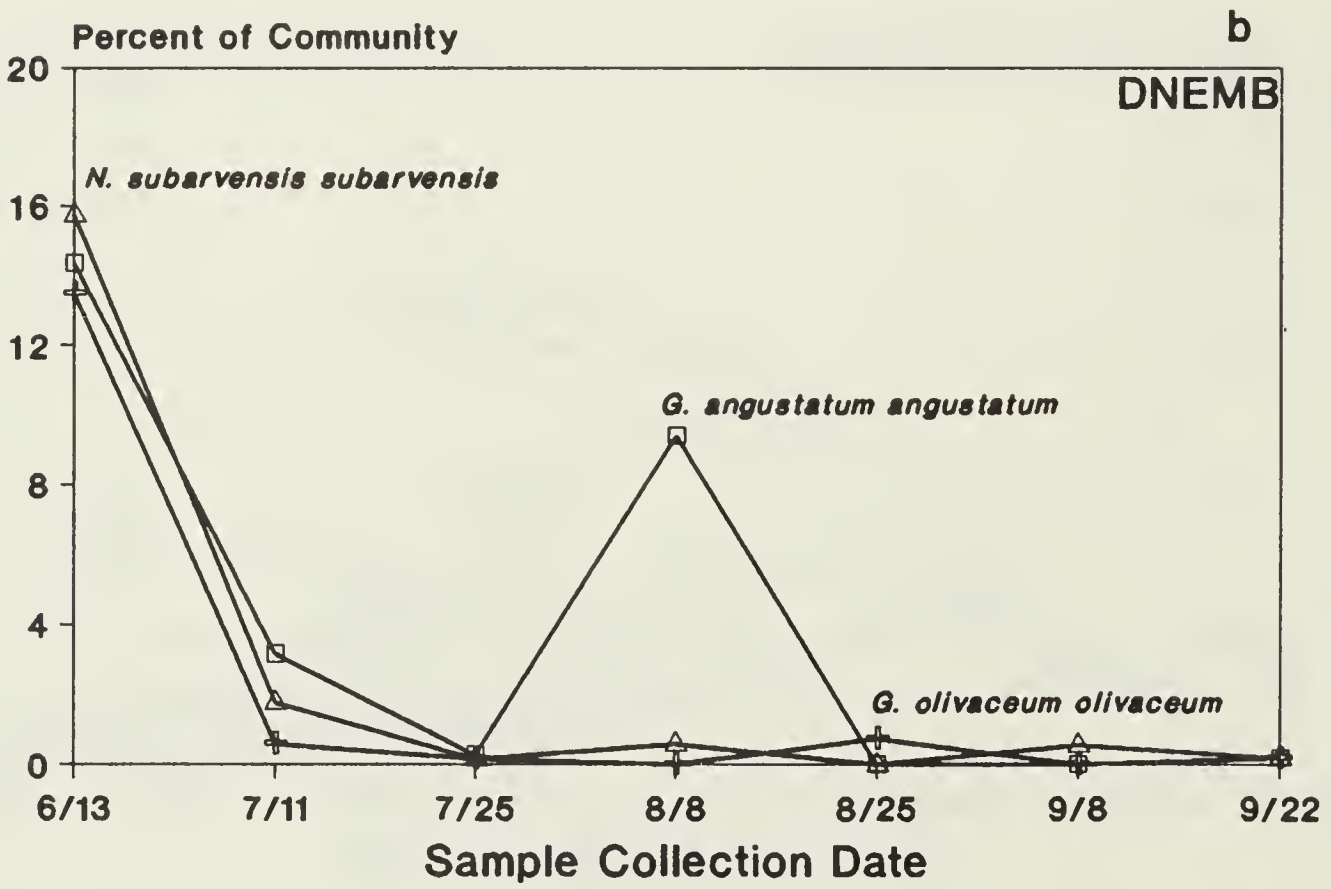


Figure 7. Relative abundance of *N. subarvensis subarvensis* from 13 June 1990 through 22 September 1990 at UPBFK (a) and DNBFK (b).

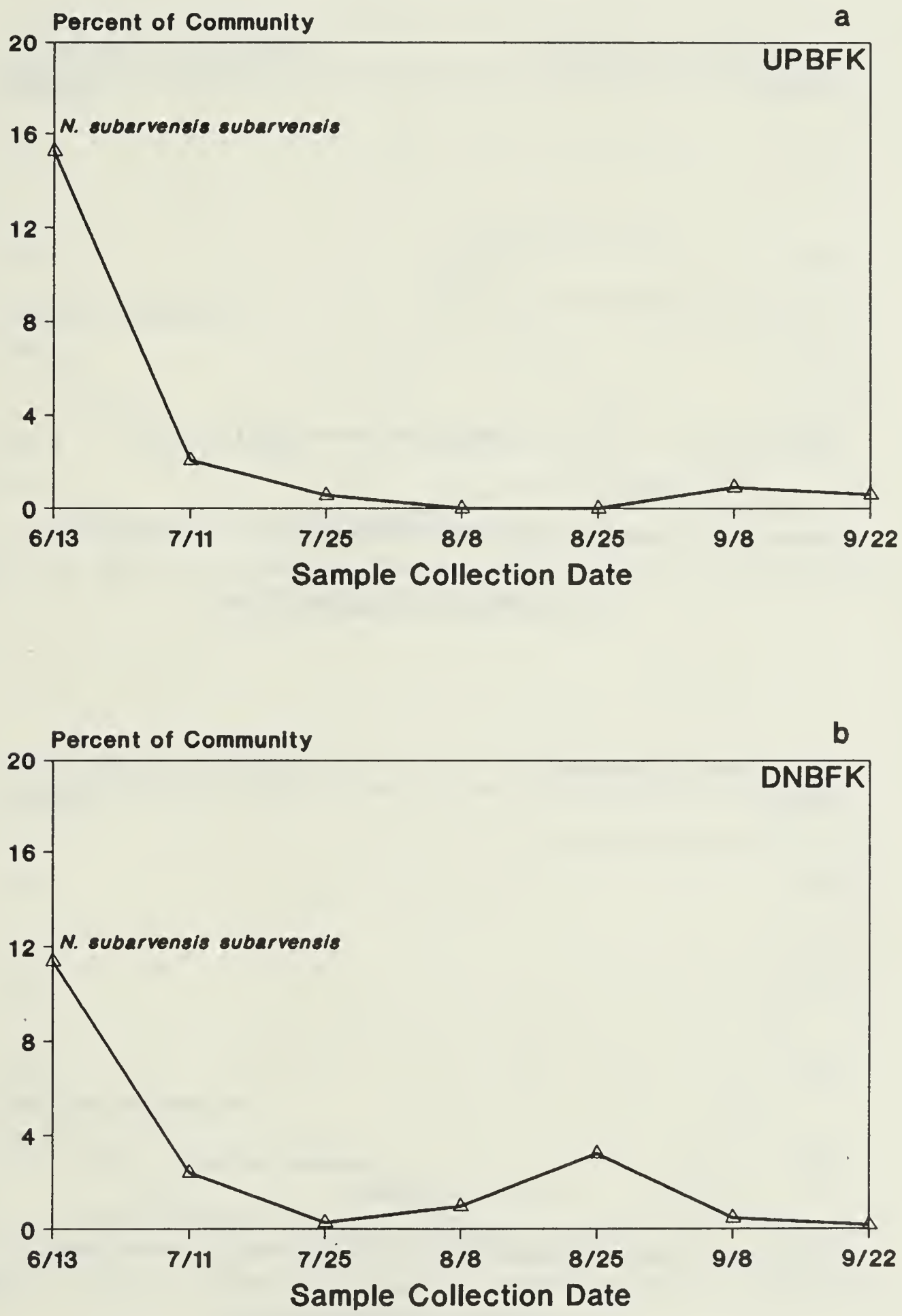
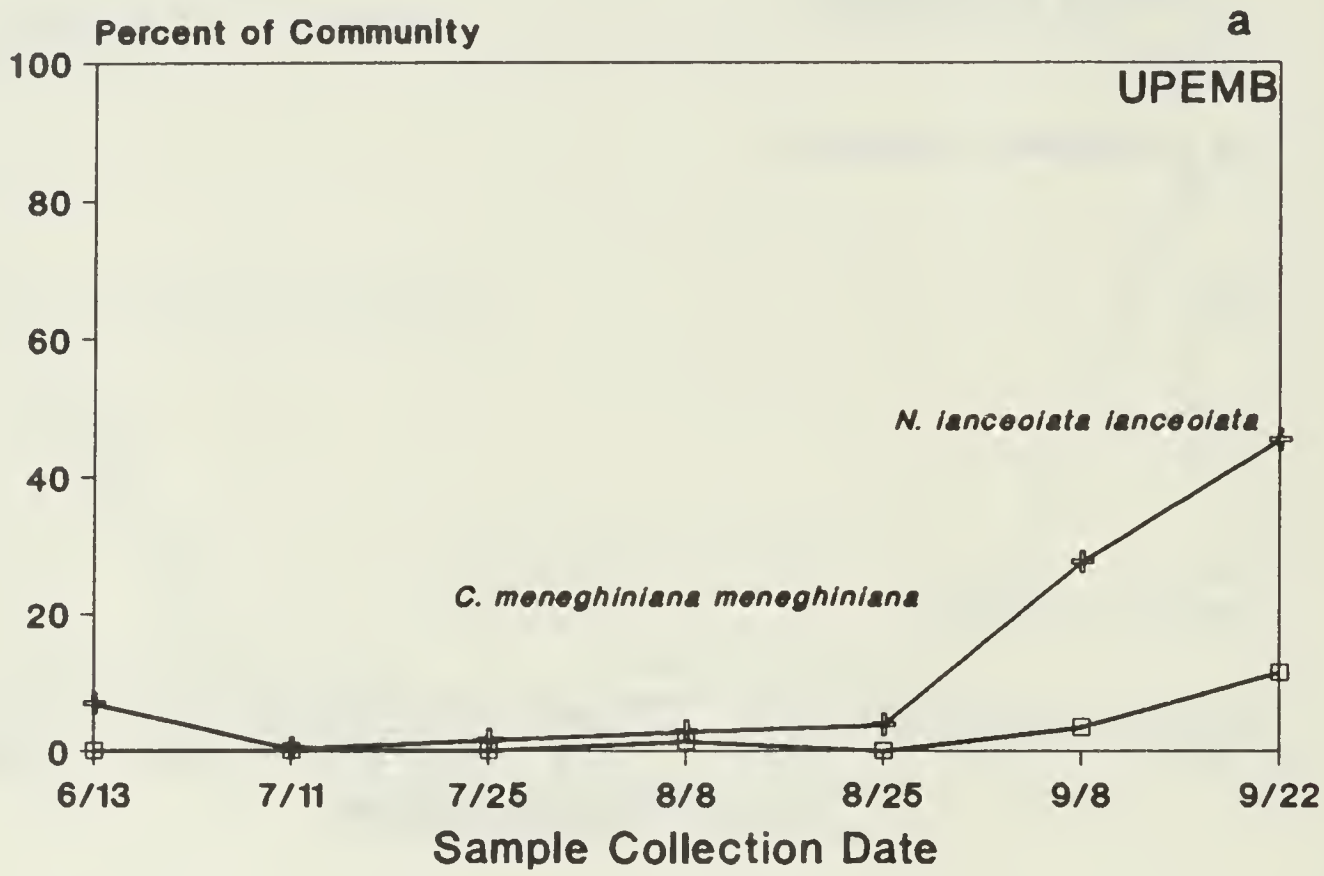


Figure 8. Relative abundance of *C. meneghiniana meneghiniana, N. lanceolata lanceolata*, and *N. amphibia amphibia* from 13 June 1990 through 22 September 1990 at UPEMB (a) and DNEMB (b).



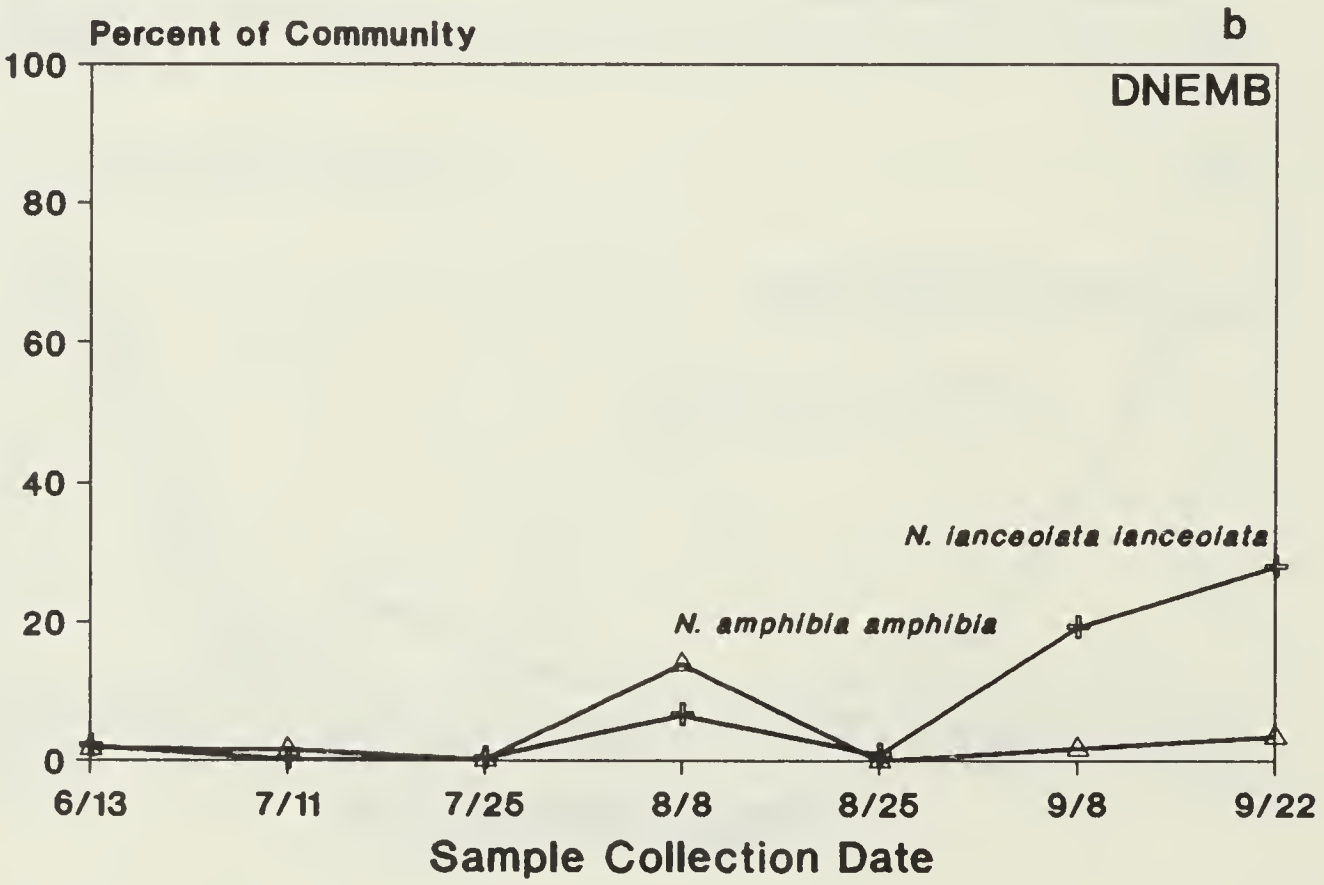
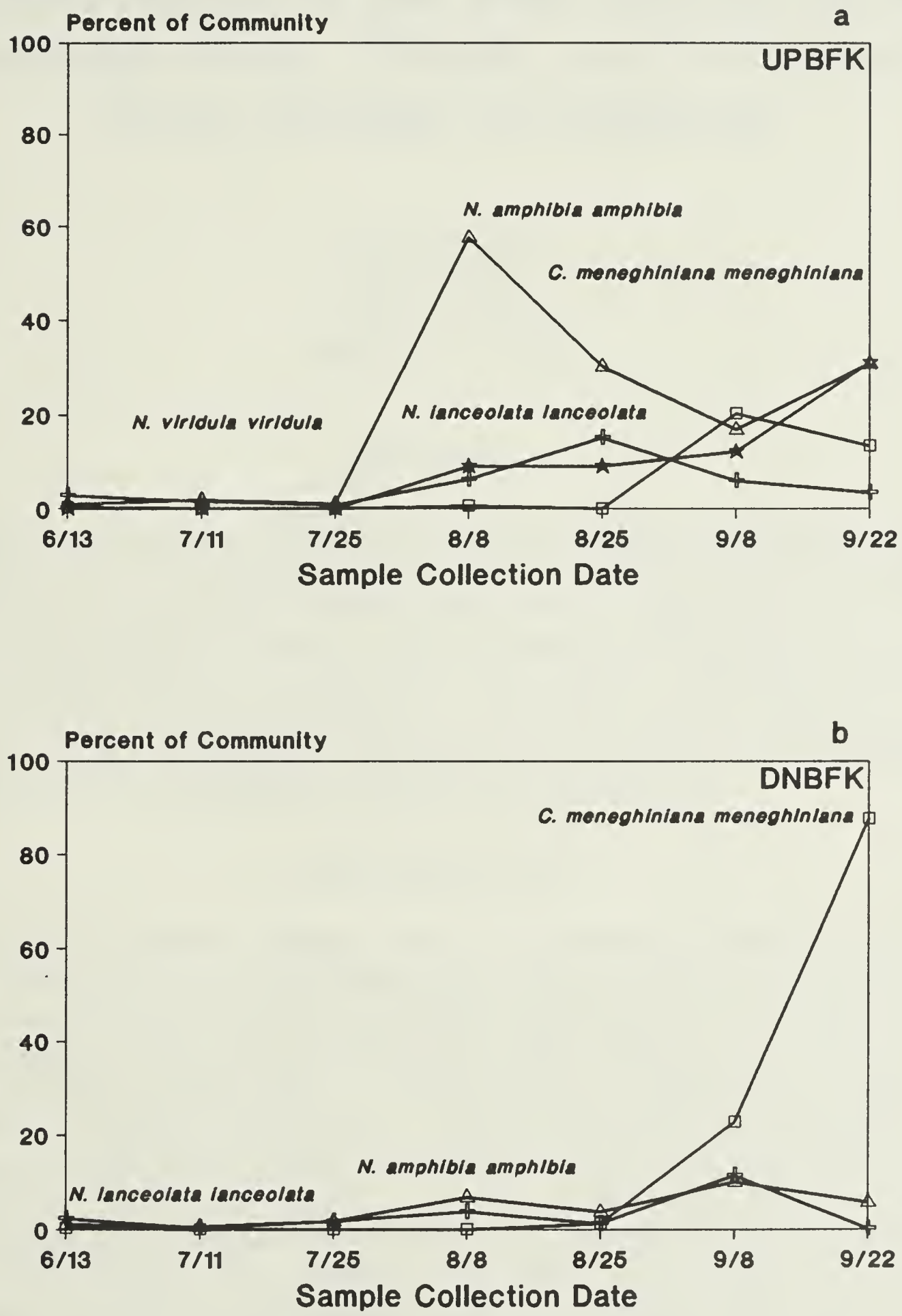


Figure 9. Relative abundance of *C. meneghiniana meneghiniana, N. lanceolata lanceolata, N. viridula viridula*, and *N. amphibia amphibia* from 13 June 1990 through 22 September 1990 at UPBFK (a) and DNBFK (b).



Transactions of the Illinois State Academy of Science
(1994), Volume 87, 1 and 2, pp. 29 - 35

The Extent of Anthropogenic Disturbance on the Aquatic Assemblages of the East Branch of the DuPage River, Illinois, as Evaluated Using Stream Arthropods

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ABSTRACT

The extent of anthropogenic disturbance on the aquatic assemblages of the East Branch of the DuPage River was evaluated using arthropods as indicator species. Hilsenhoff's arthropod index measurements reflected a stream which is organically polluted. These findings were partially supported by selected chemical measurements of ammonia-nitrogen, nitrate-nitrogen, orthophosphate, and chloride. Sampling yielded an impoverished list of ten taxa dominated by *Simulium vittatum* and hydropsychid caddisflies. Another possible source of disturbance is the extensive physical disruption of the stream in the form of streambed stabilization and channelization.

INTRODUCTION

Prior to European settlement, DuPage County was covered by oak savanna and marshland (Lampa 1985). By the end of the 19th century, a large portion of the county had been converted to farmland. Urbanization followed and today the county is residence to over 760,000 people. Natural areas remaining are largely limited to the DuPage County Forest Preserves, of which many are located along two streams; the East and West Branches of the DuPage River (Figure 1). Despite the protection of the preserves, the streams are anthropogenically disturbed by effluents from municipal waste water treatment plants (MWWTP), surface runoff, and physical disturbance such as siltation, channelization, and streambed stabilization (Illinois Environmental Protection Agency [IEPA] 1988, Petersen 1991, Petersen et al. 1992). In this study, the extent of anthropogenic disturbance on the aquatic assemblages of the East Branch of the DuPage River (E. Branch) was evaluated using stream arthropods as indicator organisms.

The E. Branch joins the W. Branch just south of DuPage County to form the DuPage River (Figure 1). Physical characteristics of the E. Branch are given in Table 1. The stream has been extensively modified by efforts to stabilize the streambed and by channelization. These modifications have given the E. Branch the appearance of a canal, especially along its lower half. Larger substrates within the stream are commonly limited

to cobble underneath bridges and fragmented concrete used to stabilize the streambed. Nine MWWTPs which service more than 300,000 residents in communities near the E. Branch discharge into it. Only 20% of the stream's length is within protected DuPage County Forest Preserves. Most of the remainder flows through residential areas and along or beneath roadways including Interstates 88 and 355 (Figure 1).

Aquatic arthropods were chosen as environmental indicators because they show a wide range of sensitivities to anthropogenic disturbance (Extence et. al. 1987, Hilsenhoff 1987, Ohio Environmental Protection Agency 1987, Paine and Gaufin 1956, Whitehurst and Lindsey 1990). Hilsenhoff's arthropod index (Hilsenhoff 1987) was used to quantify observations. The index was designed to measure the water quality in organically enriched waters. However, it may also be sensitive to other forms of anthropogenic disturbance such as stream modification (Petersen 1991).

Selected chemical measurements were taken to provide back-ground information. These included pH and measurements of chemicals commonly associated with organic pollution: ammonia-nitrogen, nitrate-nitrogen, orthophosphate, and chloride. Besides indicating possible MWWTP contributions to lower water quality, higher chloride concentrations during winter could indicate contributions from roadways in the form of salt runoff.

METHODS

Four sampling sites were located along the E. Branch (Figure 1). The procedures for collecting stream arthropods at these sites were those of Hilsenhoff (1987). Sampling sites were located in riffles with depths of <10cm. Collections were taken using a D-framed dip net at two to three week intervals from October, 1991, through April, 1992. Summer sampling was neglected because of a reduced fauna as many species emerge to reproduce. Each sample consisted of 100 arthropods. Specimens were preserved in 70% ethanol and identified to species when possible. Voucher specimens have been retained at College of DuPage.

Except for *Cheumatopsyche* spp. and *Simulium vittatum* Zetterstedt, pollution tolerance values (PTVs) used to calculate Hilsenhoff's index were taken from Hilsenhoff (1987). *Cheumatopsyche* spp. were assigned a PTV value of 6 (up from Hilsenhoff's PTV of 5) to continue with the assignment given to the genus in the W. Branch River System (Petersen 1991) and in view of similar chemical characteristics to streams of this system. The PTV of *S. vittatum* was raised from 7 to 8 after finding the black fly cohabiting severely polluted sections of the W. Branch River System with *Caecidotea intermedius* (Forbes) and *Chironomus* spp. (Petersen 1991, Petersen et. al. 1992). Hilsenhoff (1987) has assigned the latter two species PTVs of 8 and 10, respectively.

Chemical measurements of ammonia-nitrogen, nitrate-nitrogen, orthophosphate, and chloride were taken during arthropod collection periods from each sampling site using LaMotte chemical testing kits (LaMotte Chemical Products Company). Measurements of pH were begun March, 1992, and were taken during arthropod collections.

RESULTS AND DISCUSSION

An impoverished list of ten taxa was generated from the E. Branch (Table 2). Collections were dominated by a black fly (*Simulium vittatum* Zetterstedt) and caddisflies (*Cheumatopsyche* spp. and *Hydropsyche betteni* Ross). These species are relatively tolerant to anthropogenic disturbance (Hilsenhoff 1987, Ross 1944, Petersen 1991). Hilsenhoff's arthropod index measurements reflected a stream that is moderately disturbed (Table 3).

Concentrations of selected chemicals were somewhat elevated (Table 3), and as has been found by the IEPA (1988), ranged to levels which can be expected from organically polluted waters. The pH values were measured to be similar among sites on a given sampling event (all 7.75±0.29(4); $\bar{x}\pm s(n)$). Chloride concentrations tended to be higher during the winter months of January through March among sites (Table 4). However, it is unknown if salt used to deice roads contributed to these higher measurements. More frequent sampling of sites, and of soil from road embankments near sites throughout the year, would be necessary to verify this.

Biotic indices and chemical measurements from the E. Branch tended to be similar or lower than those from the W. Branch River System obtained following similar procedures (Petersen 1991, Petersen et al. 1992). Among sampling sites along the W. Branch and its tributaries, mean biotic indices ranged from 6.28 to 8.94, mean ammonia-nitrogen measurements from 0.41 ppm to 7.00 ppm, mean nitrate-nitrogen measurements 0.32 to 2.53 ppm, mean chloride measurements from 104 ppm to 452 ppm, and mean orthophosphate measurements from 0.27 to 1.36 ppm. However, the W. Branch River System supports a richer arthropod fauna. Twenty-six taxa of arthropods [including *Psephenus herricki* (DeKay)] have been collected from the W. Branch. The number of arthropod taxa collected from the E. Branch is comparable to the 7 to 15 taxa collected from the small tributaries of the W. Branch River (see Table 1 for physical measurements of the W. Branch and its tributaries). The biotic index measurements and selected chemical analyses fail to explain the disparity between E. Branch and W. Branch arthropod faunas. While unidentified chemical pollution may contribute to the impoverished arthropod assemblages in the E. Branch, additional causes may be the lack of habitat heterogeneity and suitability as affected by extensive physical disruption. Future studies may want to discriminate among these forms of anthropogenic disturbance.

ACKNOWLEDGEMENTS

I extend my appreciation to the Forest Preserve District of DuPage County for supporting the research and B. Petersen for commenting on the manuscript.

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Figure 1. Locations of the sampling stations within the East Branch of the DuPage River, DuPage County, Illinois. Also shown is the West Branch of the DuPage River and its major tributaries. Symbols: EB = E. Branch; A = Ackerman Park site; P = Prairie Path site; H = Hidden Lake Forest Preserve site; B = Burlington Avenue site; WB = W. Branch; Kl = Kline Creek, Kr = Kress Creek, SB = Spring Brook Creek, Wi = Winfield Creek, ● identifies sampling sites and ▲ identifies waste water treatment plants near the E. Branch sampling sites.

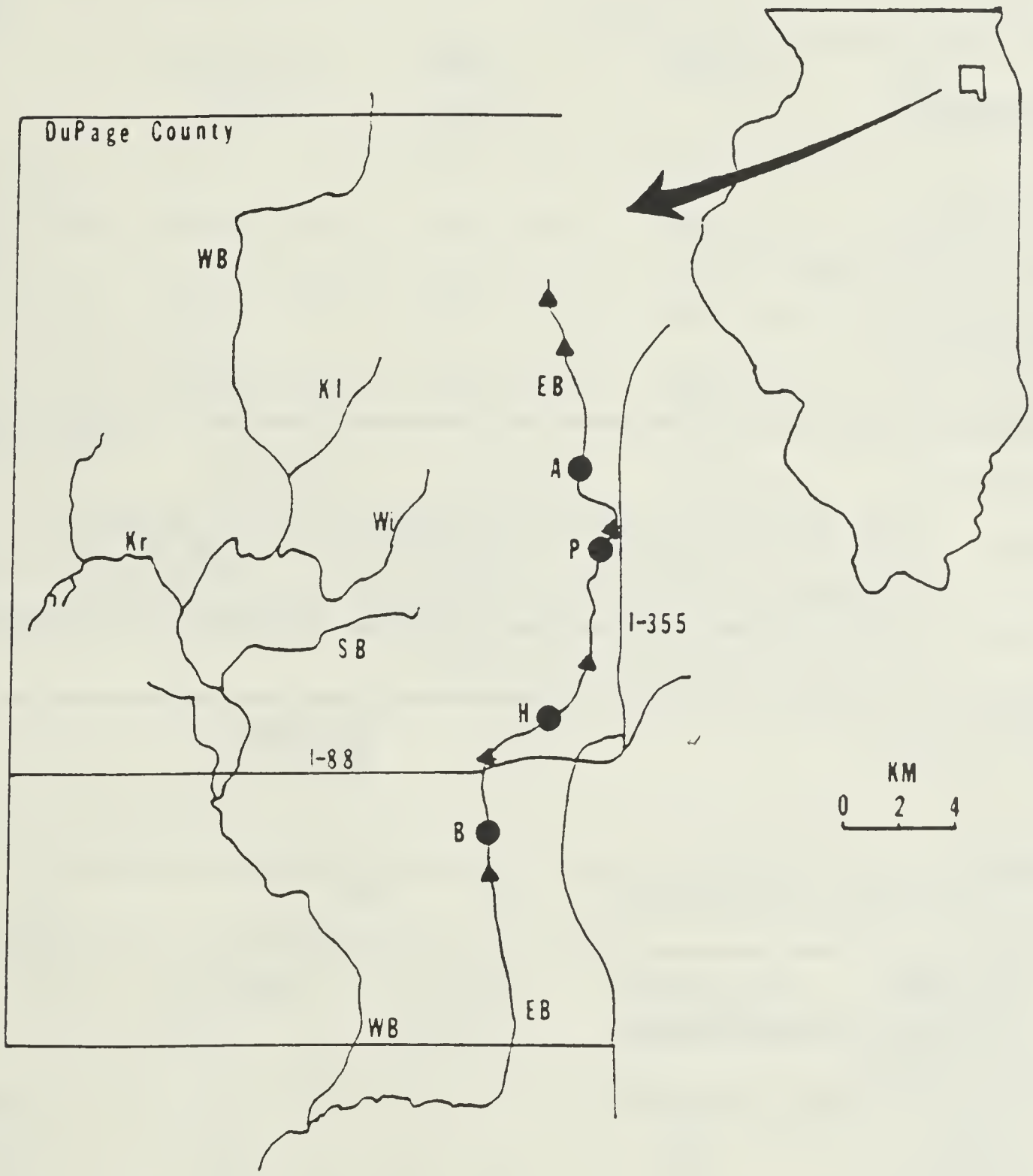

Table 1. Physical characteristics of the East Branch of the DuPage River, West Branch of the DuPage River, plus the tributaries of the West Branch of the DuPage River: Kline Creek, Kress Creek, Spring Brook Creek, and Winfield Creek as taken from the Northeastern Illinois Planning Commission (1978).

Stream	Length (km)	Average width (m)	Average gradient (m/km)	Drainage (km^2)
The East Branch of the DuPage River	39.5	9.8	0.74	218
The West Branch of the DuPage River	45.6	47.9	0.70	974
Kline Creek	7.4	2.4	2.88	32
Kress Creek	12.1	3.1	1.25	48
Spring Brook Creek	8.0	3.0	1.29	18
Winfield Creek	11.6	1.8	1.42	23

Table 2. Arthropods collected from the East Branch of the DuPage River according to sampling site and abundance. Symbols: PTV = pollution tolerance value; A = Ackerman Park site, P = Prairie Path site, H = Hidden Lake Forest Preserve site, and B = Burlington Avenue site.

Order Species	PTV	Abundance A	P	H	B
Isopoda					
Caecidotea intermedius (Forbes)	8	115			10
Odonata					
Argia spp.	6	4		12	23
Hetaerina americana Fabricius	6			1	
Ephemeroptera					
Stenacron interpunctatum (Say)	7			1	8
Coleoptera					
Berosus sp.	6		1		
Stenelmis crenata (Say)	5	1	1		30
Trichoptera					
Cheumatopsyche spp.	6	302	201	139	456
Hydropsyche betteni Ross	6	248	101	190	279
Diptera					
Cricotopus spp.	7	229	60	8	41
Simulium vittatum Zetterstedt	8	101	136	649	153

Table 3. Mean biotic index values and selected chemical concentrations (ppm) ± standard deviations (sample size) ($\bar{x}\pm s(n)$). The biotic indices are interpreted as follows: 0-3.50 indicates excellent water quality; 3.51-4.50 very good water quality; 4.51-5.50 good water quality; 5.51-6.50 fair water quality; 6.51-7.50 fairly poor water quality; 7.51-8.50 poor water quality; and 8.51-10.00 very poor water quality. Also included are chemical concentrations that can be expected from relatively unpolluted waters (Clark 1977, Klein 1962).

Location	Biotic Index	Chemical			
		Ammonia-nitrogen	Nitrate-nitrogen	Chloride	Ortho-phosphate
Ackerman Park	6.76±0.74(10)	0.39±0.33(9)	1.84±1.29(9)	209±60(11)	0.30±0.15(9)
Prairie Path	5.79±2.46(8)	1.21±2.78(7)	1.06±1.41(7)	212±90(8)	0.56±0.83(7)
Hidden Lake Forest Preserve	7.37±0.29(11)	0.28±0.26(9)	1.47±0.81(9)	263±68(12)	0.30±0.11(9)
Burlington Avenue	6.52±0.68(11)	0.28±0.26(9)	1.24±0.52(9)	250±63(12)	0.31±0.11(9)
Chemical concentrations that can be expected from relatively unpolluted waters.		<0.2	Virtually absent	<250	<0.3

Table 4. Chloride concentration measurements (ppm) according to sampling date and site.

Date	Ackerman Park	Prairie Path	Hidden Lake Forest Preserve	Burlington Avenue
22 October	200		340	324
19 November	100		180	156
2 December	136		178	188
18 December	212	248	278	260
2 January	260	280	332	300
3 February	308		368	368
2 March	268	264	304	268
9 March	220	188	240	260
6 April	236	240	288	232
20 April	200	212	212	220

Transactions of the Illinois State Academy of Science
(1994), Volume 87, 1 and 2, pp. 37 - 41

Early Season Nesting Success of Mourning Doves *(Zenaida macroura)* in Central Illinois

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ABSTRACT

Early season mourning dove (*Zenaida macroura*) nests are subjected to cold weather which may reduce fledging success. In a residential setting in central Illinois, a wind storm destroyed 50% of all nests and fledging success was only 13.7% because of the storm and low hatching success of eggs that remained in the nests. Although early season nests may often have low reproductive success, if they are successful, they may result in fledglings that can breed by the end of the season.

INTRODUCTION

Mourning doves *(Zenaida macroura)* are common nesting birds on the campus of the University of Illinois in Urbana/Champaign. They begin to nest in early March and continue until early October (Hanson and Kossack 1963, Geissler et al. 1987). Young are initially fed protein-rich crop milk, which causes quick growth of the young, but also constrains clutch size to two eggs (Lack 1948, Westmoreland and Best 1987, Blockstein 1989). Partly because of their small clutch size, mourning doves can and must produce multiple clutches throughout a long nesting season to produce enough young to compensate for mortality (Westmoreland et al. 1986).

Many aspects of the mourning doves' life history are based on the need to produce multiple clutches in a year (Westmoreland et al. 1986). For example, mourning doves produce eggs that are smaller than would be expected for the size of the adults and the young do not fledge at their maximum size. The pair bond is strong, saving time between clutches because they don't have to find new mates. The nest is a simple platform of sticks usually placed along the branches of a fir, pine or spruce or it may be placed on top of an existing nest of another species (Hanson and Kossack 1963). The nest may be reused and if it is destroyed, it is easy to replace. The result of these adaptations is that if one clutch fails, it can be replaced quickly and easily. Therefore, losses early in the breeding season may have little effect on the adult's overall fitness, and successful nests may produce young that may be able to reproduce later in the breeding season, before the period of high winter mortality (Irby and Blakenship 1966, Armstrong and Noakes 1977, Mirachi et al. 1980, White et al. 1987). With the increased reproductive success of the young there is a corresponding increase in the fitness of the

parents. Such a potential for increased fitness and the low cost of a single clutch selects for nesting as early as the environment allows.

One of the major obstacles to successful nesting may be cold and inclement weather. Hanson and Kossack (1963) noted that the beginning of the nesting season was correlated with temperature. Mourning doves nested early in warm years and later in cold years. Late winter and early spring weather is not entirely predictable though, and sudden cold, strong wind, rain, or snow may adversely affect the survival of offspring and may destroy poorly constructed nests (Coon et al. 1981).

In my study, a population of mourning doves in and near the campus of the University of Illinois in Urbana/Champaign was studied to determine the fledging rate of early nesters in relation to early spring weather.

METHODS

Starting in early March, 1991, I initiated a thorough search of trees and shrubs on the campus of the University of Illinois and the immediate surrounding areas in Champaign/Urbana for the presence of mourning dove nests. Particular attention was paid to evergreen trees where mourning doves seem to prefer to lay their eggs in Illinois (Hanson and Kossack 1963), although bushes and deciduous trees, as well as the ground, were searched.

Every other day, I checked for the presence of eggs or young by the use of a mirror attached to a long pole. The two nests that were beyond the length of the pole were excluded from the study. All clutches observed had successfully fledged, or were either abandoned or naturally destroyed by the second week of April.

The incubation period for eggs is 14 days and the young usually fledge 12 days later. Since it was possible for the offspring to leave the nest 10 days after hatching (Geissler et al. 1987), young were said to have successfully fledged on their tenth day. Eggs were considered to be dead after 16 days and were opened to check for fertility after the parents had abandoned them. Dead eggs were assumed to have survived for fourteen days. Nests that were destroyed due to an unknown cause on an unknown day were assumed to have been destroyed on the day between visits.

Nesting data were analyzed using the Mayfield (1961) estimate for survival rate during the incubation and nestling periods:

$$\text{Fledging Rate} = \left(\begin{array}{c}\text{Daily egg}\\ \text{survival rate}\end{array}\right)^{E} \times \left(\begin{array}{c}\text{Daily nestling}\\ \text{survival rate}\end{array}\right)^{N} \times 100$$

$$= \left(1 - \frac{\text{Dead Eggs}}{\text{Egg Days}}\right)^{E} \times \left(1 - \frac{\text{Dead Nestlings}}{\text{Nestling Days}}\right)^{N} \times 100$$

where E is the maximum number of days exposed as an egg (= 14 days) and N is the maximum number of days exposed as a nestling (= 10 days). Egg days and nestling days are defined as the total number of days that all eggs and nestlings, respectively, were observed in nests.

RESULTS

Based on the data from the twenty-five nests (Table 1) that were found containing a total of 48 offspring, the daily egg survival rate was 88.4% with an overall egg survival rate of 17.8%. The daily nestling survival rate was 97.4% with an overall nestling survival rate of 77.1%. The fledging rate for the population was 13.7%.

The main cause of mortality was a wind storm on 27 March, 1991, which destroyed 12 of 24 nests (50%). The winds were the strongest of the year, reaching gusts up to 22.3 m/sec (Illinois State Water Survey pers. com.). Any egg-bearing nest that was not protected from the wind was blown down and the eggs were lost. Wind also destroyed nests on other days, but it never affected any offspring after they hatched.

None of the eggs were removed by predators. All the eggs that were counted as dead had either fallen out of the nest or remained in the nest beyond 16 days, but never hatched. All abandoned eggs were in an advanced state of development, thus, they were not abandoned because they were infertile. The fate of the two nestlings that were considered dead is unknown.

DISCUSSION

Early season mourning dove nesting success for the University of Illinois population was very low. In comparison, Geissler et al. (1987) determined a 33% fledging rate for non-hunted areas of the United States and a 26% fledging rate for areas in which the birds were hunted. The 13.7% fledging rate for this study fell much below the previous studies' findings due to cold and inclement weather, particularly the wind storm, and its effects on egg mortality.

In addition to wind, cold temperatures may also have an effect on egg survival. The average low temperature for March 1991 was only 0.7° C (Illinois State Water Survey, pers. comm.). A correlation between daily temperature and nest success could not be performed because adults guarded eggs long after they had presumably died so that the exact day on which the eggs died could not be determined. However, it is likely that low temperatures during the night may stress the eggs and may be a cause of egg mortality for unhatched eggs that were not otherwise destroyed.

Predation was not a source of egg mortality in this population although I have seen several potential predators in the area, including eastern gray squirrels (*Sciurus carolinensis*), cats (*Felis domesticus*), opossums (*Didelphis marsupialis*), common grackles (*Quiscalus quiscula*), and blue jays (*Cyanocitta cristata*). In fact, abandoned nests often still had eggs in them several days after the parents stopped guarding them, even though the bright white eggs were conspicuous in the nests. Grackles were commonly observed roosting in one particular tree where a nest had been abandoned. The grackles, however, did not touch the single egg and it eventually was blown from the nest.

When I checked the nests, the guarding parent usually flushed, thereby exposing the eggs to the elements. The effects of such exposure are unknown, however, no pair ever

abandoned the nests because of my frequent visits. When nests were abandoned, the embryo always appeared to be in an advanced state of development and had presumably been abandoned because it could not hatch.

For early nesting mourning doves, a major threat to fledging success is cold and inclement weather. Mourning doves, however, continue to nest early because the loss of an individual clutch does not represent a great deal of investment and it can be replaced quickly. With the benefits of multiple clutching and the ability to nest by hatching-year birds, mourning doves would be expected to nest as early as the environment allows.

ACKNOWLEDGEMENTS

I would like to thank Scott K. Robinson and Lawrence M. Page for their comments on the manuscript. I would also like to thank Karl Halupka for encouraging me to publish these data and also Salon Morse and W. Douglas Robinson for help in the formulation of this study.

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Table 1: Suvivorship Data based on number of eggs originally in the nest

# of Eggs in Nest	# of Nests	# of Eggs	# of Eggs Hatched	# of Nestlings Fledged	Egg Days	Nestling Days	Daily Egg Survival Rate	Daily Nestling Survival Rate	Fledging Rate
One	3	3	0	0	10	0	70.0%	0.0%	0.0%
Two	19	38	6	4	246	58	87.0%	96.6%	10.0%
Three	2	6	2	2	80	20	95.0%	100%	18.8%
Totals	24	47	8	6	336	78	88.4%	97.4%	13.7%

Transactions of the Illinois State Academy of Science
(1994), Volume 87, 1 and 2, pp. 43 - 45

Some Helminths of the Racer, *Coluber constrictor*, and the Eastern Hognose Snake, *Heterodon platirhinos*, in Southern Illinois

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ABSTRACT

Ochetosomatid digeneans found in snakes collected from southern Illinois included *Ochetosoma kansense* from *Coluber constrictor* and *Ochetosoma elongatum* from *Heterodon platirhinos*. The finding of *Ochetosoma kansense* in *Coluber constrictor* represents a new host record. The cosmocercoid nematode, *Cosmocercoides variabilis*, found in *Heterodon platirhinos* also represents a new host record.

INTRODUCTION

Few references are available on the helminths of snakes in Illinois and especially so on the eastern hognose snake, *Heterodon platirhinos* Latreille, and the racer, *Coluber constrictor* Linnaeus. Dyer (1970) reported ochetosomatid digeneans *Ochetosoma elongatum* (Pratt, 1903) Goodman, 1952 from the lungs of *Heterodon platirhinos* collected in Williamson County and *Ochetosoma ellipticum* (Pratt, 1903) Caballero and Vogelsang, 1947 from the mouth of *H. platirhinos* collected in Jackson County. Later, Dyer and McNair (1974) reported *Ochetosoma elongatum* from the mouth, esophagus, stomach, and intestine of *H. platirhinos* collected in Jackson County. To my knowledge, there are no reports on the helminths of *Coluber constrictor* in Illinois. The present report is concerned with the detection of ochetosomatid digeneans in *H. platirhinos* and *C. constrictor* and a cosmocercoid nematode in *H. platirhinos*.

MATERIALS AND METHODS

Digeneans were removed from the oral cavity of a single *Coluber constrictor* collected on April 30, 1992, from Heron Pond, Johnston County by Anthony Gerard. Helminths of *Heterodon platirhinos* were obtained from the water dish of an isolated and confined female snake housed in the laboratory of Dr. Ronald Brandon, Department of Zoology, Southern Illinois University at Carbondale. The snake was obtained on April 21, 1993, from Larry Keller, who said it was from Union County. The digeneans were fixed in warm alcohol-formalin-acetic acid (AFA), stained with either Harris' hematoxylin or Grenacher's alcoholic borax carmine, dehydrated, cleared in beechwood creosote, and mounted in Canada balsam. Nematodes were fixed in hot 70% ethanol, cleared in glycerin-alcohol,

and studied as temporary mounts in pure glycerine. Voucher specimens were deposited in the United States National Museum Helminthological Collection (USNM Helm. Coll.) as noted.

RESULTS AND DISCUSSION

Dronen and Guidry (1977) studied differences in measurements of morphological features between live and fixed specimens of *Ochetosoma aniarum* and *Ochetosoma ellipticum*, concluding that the absolute dimensions of various body parts are inadequate criteria for differentiating species of *Ochetosoma*. This may be due to the fact that fixation techniques are not standardized and because some specimens have been described from live material and others from fixed material. In the present report, identification of specimens of *Ochetosoma* were based on the criteria used by Brooks (1979) in differentiating species of this genus, namely, the vitelline configuration, the sucker ratio, the location of the genital pore, the posterior extent of the cirrus sac, and the amount of glandulation inside the cirrus sac. Specimens from *Coluber constrictor* were identified as *Ochetosoma kansense*, and specimens from *Heterodon platirhinos* as *Ochetosoma elongatum* (Pratt, 1903) Goodman, 1952. Voucher specimens of *Ochetosoma kansense* and *Ochetosoma elongatum* have been deposited as USNM Helm. Coll. No. 82954 and No. 82953, respectively.

Ochetosoma kansense has been reported previously by Yamaguti (1971) from the mouth, esophagus, and lungs of several snakes including the northern copperhead, *Agkistoodon contortrix mokasen*, the western cottonmouth, *A. piscivorus*, the pigmey rattlesnake, *Sistrurus miliarius*, the Mississippi ringneck snake, *Diadophis punctatus stictogenys*, and *Heterodon platirhinos*. Dyer (1970) reported *O. kansense* from the gray rat snake, *Elaphe obsoleta spiloides* and *Lampropeltus* sp. and Dyer and McNair (1974) report it from the kingsnake, *Lampropeltus getulus*. The present report represents the first finding of *Ochetosoma kansense* from *Coluber constrictor* in Illinois. *Ochetosoma elongatum* has been reported previously in *Heterodon platirhinos* from Illinois by Dyer (1970) and by Dyer and McNair (1974).

Nematodes of the genus *Cosmocercoides* Wilkie, 1930 (Cosmocercoidea, Cosmocercidae) are frequent parasites of amphibians and reptiles in North America. Previous to the work of Vanderburgh and Anderson (1987) most investigators considered the cosmocercoid nematode common to amphibians and reptiles as belonging to a single species, namely, *Cosmocercoides dukae* (Holl, 1928) Travassos, 1931. *Cosmocercoides dukae* has also been identified from terrestrial molluscs (Ogren 1953, 1959; Anderson 1960; Lewis 1973; Riggs and Ulmer 1983). As pointed out by Anderson (1984), few nematode species parasitic in vertebrates are known to mature in invertebrates. Comparative studies by Vanderburgh and Anderson (1987) of nematodes of the genus *Cosmocercoides* from toads and slugs revealed that the worms generally considered to belong to the same species (*C. dukae*) were not conspecific. *Cosmocercoides dukae*, normally a parasite of molluscs, may occur accidentally in amphibians and reptiles which feed on molluscs. *Cosmocercoides variabilis* (Harwood, 1930) Travassos, 1931 was resurrected as the name of the species occurring in amphibians and reptiles. Specimens in the present study were identified as *Cosmocercoides variabilis*. Voucher specimens of *C. variabilis* have been deposited as USNM Helm. Coll. No. 82955.

This is the first report of this nematode from *Heterodon platirhinos*. Baker (1978) reinvestigated the development of *Cosmocercoides* in toads and verified Harwood's (1930) claim that larvae penetrate the skin and develop in the lungs before taking up residence in the intestine. Parasites found in the water dish of *H. platirhinos* in the present study were probably migrating from the lungs to the rectum via the trachea and mouth.

ACKNOWLEDGMENTS

Snakes and host data were made available by Dr. Ronald Brandon, Department of Zoology, Southern Illinois University at Carbondale. Dr. Brandon also kindly reviewed the manuscript.

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Transactions of the Illinois State Academy of Science
(1994), Volume 87, 1 and 2, pp. 47 - 50

The Western Harvest Mouse (*Reithrodontomys megalotis*) Moves into Northeastern Illinois

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ABSTRACT

Three western harvest mice, *Reithrodontomys megalotis*, were collected in the Waterfall Glen Forest Preserve in DuPage County in June and July 1988. The mice were found in a grassy area of the preserve dominated by poverty grass (*Danthonia spicata*). This finding represents a northeastern extension of the range of *R. megalotis* in Illinois.

INTRODUCTION

The western harvest mouse, *Reithrodontomys megalotis,* was first reported in Illinois from northwestern Carroll County in 1953 (Hoffmeister and Warnock, 1955). Thereafter, *R. megalotis* was repeatedly found in surrounding northwestern counties north of the Illinois River (Klimstra, 1957; Stains and Stuckey, 1960; Verts, 1960). By 1962 *R. megalotis* was also found south of the Illinois River in Tazewell and Morgan counties (Stains and Turner, 1963) and continued to spread slowly south and east in the state (Birkenholz, 1967; Birkenholz, 1973; Pinkham and Meade, 1970). Stupka *et al* (1972) described the presence of *R. megalotis* in DeKalb County and mentioned a record of collection in DuPage County. This capture occurred in 1962 and is described by Hoffmeister (1989) as most likely in Lake (or possibly Cook) instead of DuPage County.

Whitaker and Sly (1970) first collected *R. megalotis* in Indiana in Newton County in 1969. Ford (1977) described the geographical distribution of *R. megalotis* in Indiana to be bounded on the south by Interstate 74, by the Tippecanoe River at the east, and by the Kankakee River at the north. No *R. megalotis* had been captured by Ford north of the Kankakee River despite 18,000 trap nights of effort. Becker (1975) reported the first record of *R. megalotis* east and north of the Des Plaines and Kankakee River systems in Illinois based on specimens trapped in Will County. No *R. megalotis* have been reported north of the Kankakee River in Indiana.

This paper reports the first records of *R. megalotis* in DuPage County and extends the known range of the species in Illinois.

MATERIALS AND METHODS

As part of a project on external parasites of the white-footed mouse (*Peromyscus leucopus*), three different habitats were live trapped periodically from June 4 through September 8, 1988. All trapping was done in the Waterfall Glen Forest Preserve in the southeast corner of DuPage County. The three habitats sampled have been referred to by the Forest Preserve District of DuPage County as savanna, pine plantation, and poverty (grass) prairie. The savanna is an open oak woods which was cleared leaving large oak (*Quercus* spp.) and shagbark hickory (*Carya ovata*) trees. The understory has moderate to dense cover including shrubby dogwoods (*Cornus* spp.), poison ivy (*Toxicodendron radicans*), blackberries (*Rubus* sp.), and various species of grasses. The pine plantation consists of secondary growth of pines (*Pinus* sp.). Many dead conifers are present, both standing and fallen. The understory consists mostly of forbs. Poverty prairie is an open field containing poverty oat grass (*Danthonia spicata*) as the dominant species along with prairie dock (*Silphium terebinthinaceum*), compass plant (*Silphium lacinatum*), coneflowers (*Ratibida pinnata*) and wild strawberry (*Fragaria* sp.). The soil is sandy and also supports patches of dogwood (*Cornus* sp.) and honeysuckle (*Lonicera* sp.).

Each habitat was sampled using a ten by five trapping grid, with ten meters between trapping stations. Each trapping station within the grid contained two Sherman live traps (7.6 x 8.9 x 22.9 cm) baited with peanut butter. One hundred traps were set per trapping grid, and baited traps were left in place for three consecutive nights. Habitats were sampled on June 4-9, June 26-July 1, and September 3-8, 1988. Traps were checked each morning within two to three hours of sunrise.

Animals captured were identified to species, sexed, weighed, examined for external parasites and reproductive condition, given an identification number by toe clipping, and released.

RESULTS

Three *R. megalotis* were collected (one adult male on June 8, one adult female on June 30, and one adult female on July 1) from poverty prairie during 900 trap nights between June 4 and September 8, 1988. No *R. megalotis* were collected from the savanna or the pine plantation despite 900 trap nights per habitat over the same period of time. Other mammals collected from poverty prairie included the white-footed mouse (*P. leucopus*), the prairie vole (*Microtus ochrogaster*), the northern short-tailed shrew (*Blarina brevicauda*), and the eastern chipmunk (*Tamias striatus*).

DISCUSSION

Several maps of the distribution of *R. megalotis* in Illinois have been published (Stupka *et al*, 1972; Ford, 1977; Hoffmeister, 1989). The distribution of the mouse in the northeast corner of the state is spotty at best with records in Will (Becker, 1975) Lake (or Cook) and DeKalb counties (Stupka *et al*, 1972). This paper represents an extension of the range of *R. megalotis* in northeast Illinois into DuPage County.

The presence of *R. megalotis* in southeastern DuPage county most likely represents a movement of the species from the west rather than from the south. Hoffmeister (1989) reported a specimen from northeastern Kendall County. Representatives of these populations could have moved east across Will County into DuPage County. To us this represents a more likely scenario than a movement from the southern population reported by Becker (1975) in Will County which would represent a longer movement as well as the necessity of crossing the DesPlaines River and parallel Chicago Sanitary and Ship Canal.

We believe these results indicate a relatively recent extension of the range of *R. megalotis* into DuPage County. Small mammal surveys of Waterfall Glen Forest Preserve prior to 1988 failed to report any specimens of *R. megalotis* (D. Ludwig, personal communication). We also believe that the species is becoming established in the area although the numbers appear to be relatively low. After this study we collected other specimens from Waterfall Glen including a pregnant female with three embryos.

ACKNOWLEDGMENTS

We would like to thank Dr. Daniel R. Ludwig, Wildlife Biologist, Forest Preserve District of DuPage County for loaning us some traps and for securing permission to use the preserve for study. Some traps were purchased with a grant from the Faculty Development Committee at Elmhurst College. Dr. Ed Miller reviewed the manuscript.

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Transactions of the Illinois State Academy of Science
(1994), Volume 87, 1 and 2, pp. 51 - 59

The Anticoccidial Effects of Amprolium, Monensin And Sodium Sulfamethazine in Farm-Reared Chukar Partridges (*Alectoris graeca*) in Illinois

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ABSTRACT

Coccidian parasites were isolated from litter samples and intestinal contents of chukar partridges from a game farm and inoculated into parasite free three week old partridges medicated with amprolium, monensin and sodium sulfamethazine to determine efficacy against the parasite isolates. Amprolium exhibited no coccidiostatic activity and moderate reduction of oocyst discharge but did not prevent mortality. Monensin showed little coccidiocidal and no coccidiostatic effect against the parasites, but it did prevent mortality and morbidity as indicated by comparable body weight gains with non-infected controls. Sulfamethazine showed complete coccidiostatic activity and was moderately effective in reducing oocyst discharge while preventing mortality and minimizing morbidity.

INTRODUCTION

Chukar partridges are popular game birds and hundreds of them are raised on game preserves throughout the United States for hunting and food. The methods employed in raising partridges are very similar to those used in the poultry industry. Coccidiosis and other parasitic diseases familiar to the poultry farmer are prevalent on game farms (McQuistion and Dingman, 1986; McQuistion, 1987) causing weight loss, poor feed conversion and mortality in game birds like chukar partridges.

Six coccidial species have been described from the chukar genus *Alectoris*, however, only three species have been confirmed. The other three species are considered synonyms (Levine, 1988). *Eimeria alectoreae* (Ray and Hiregauder, 1959) was reported from India. *Eimeria kofoidi* (Yakimoff and Matikaschwili, 1936), and *E. caucasica* (Yakimoff and Buewitsch, 1932) were reported in Russia. It is not surprising that all of the coccidian species were discovered in Central Asia, the native habitat of the chukar partridge.

Anticoccidial drugs are routinely and continuously administered in the feed or drinking water of birds raised in the poultry industry to control coccidiosis; however, medication to prevent or control coccidiosis in chukars has not been documented. Three anticoccidial drugs that are readily available and used in poultry are amprolium, monensin and sodium sulfamethazine. Since these drugs are routinely added to commercial poultry feeds in the

U. S. and these poultry rations are often fed to chukars, especially among small producers, the knowledge of their efficacy on U. S. strains of chukar coccidia is important.

Amprolium was introduced in 1960 and is one of the safest anticoccidial drugs to be used extensively in the poultry industry, because it can be fed at several times its recommended dose with no ill effects (McDougald, 1982). By 1966, drug resistant strains of coccidia became a problem, so amprolium was combined with other drugs to extend and strengthen its spectrum of activity. Amprolium is still routinely added to poultry feed today.

Monensin was the first polyether ionophorous antibiotic used in commercial poultry feed, and it became a successful antibiotic in controlling morbidity and mortality from coccidiosis in poultry. Although some coccidian resistance to monensin has been reported since 1985 (Ruff et al., 1985; McDougald et al., 1986), monensin continues to be used in poultry rations.

Sulfamethazine, a sulfonamide, has a broad spectrum of activity against *Eimeria* species, despite reports of sulfonamide resistant strains of coccidia as early as 1954 (Waletzky et al., 1954). Their broad action on most endogenous stages of the avian coccidian life cycle and their water solubility have made sulfonamides an important treatment of established coccidial infections (Joyner et al., 1963).

This study was designed for two purposes. The first objective was to isolate and identify the coccidial parasites infecting chukar partridges at a private game farm in southern Illinois. The second objective was to determine the coccidiostatic and coccidiocidal effect of amprolium, monensin and sulfamethazine on the coccidian parasites isolated at the game farm.

MATERIALS AND METHODS

Collection and Identification of Parasites

Litter samples were collected from floor pens housing 3-4 week old birds from a privately owned game farm at Neoga, Illinois. The samples were mixed with 2.5% (w/v) aqueous $K_2Cr_2O_7$ and allowed to soak for 0.5h., before being filtered through No. 20, 40, and 60 mesh brass sieves. The solution was placed in a flask and air was pumped through it for seven days.

To determine the concentration of the various species of coccidia in the $K_2Cr_2O_7$ solution, 1 ml of the solution was mixed with 9 ml of saturated sugar solution. The $K_2Cr_2O_7$ sugar solution was mixed for one minute in a vortex mixer and a portion of the solution was used to fill a McMaster's counting chamber. After 15 minutes, to allow the oocysts to come to the top of the chamber, the oocysts were identified and counted with a differential counter. Absolute numbers of the various coccidial species per 1ml of actual oocyst-$K_2Cr_2O_7$ solution were calculated.

All oocyst measurements were made with a calibrated ocular micrometer on a phase contrast microscope equipped with an achromatic oil immersion objective.

Preparation of Inoculum

The filtered $K_2Cr_2O_7$ solution containing sporulated oocysts from litter samples was centrifuged (450g for 10 min) to remove the $K_2Cr_2O_7$ and diluted with distilled water to obtain 15,000 oocysts/ml. One milliliter was inoculated *per os* into 20 three week old, parasite-free chukar partridges to produce a sufficient inoculum for use in drug efficacy studies.

The birds were given non-medicated Purina® game bird ration and water *ad libitum* and placed in clean, sanitized suspended wire mesh cages. The feces were collected daily in drop pans containing 2.5% $K_2Cr_2O_7$ from Day 5 to Day 10 post-inoculation (PI). The solutions were blended, filtered and aerated for 7 days at room temprature.

The pooled $K_2Cr_2O_7$ solution representing the oocyst collection from Day 5-10 PI was centrifuged, the $K_2Cr_2O_7$ removed and distilled water added to obtain a concentration of 15,000 oocysts/ml. The inoculum was used immediately after preparation.

Experimental Design

Four week old, parasite-free chukar partridges hatched from an incubator and maintained on non-medicated Purina® game bird ration were randomly placed in five groups with five birds per group. Each group had approximately equal body weights and was housed in suspension cages 60 cm x 60 cm x 30 cm) made of 13mm (0.5 inch) square wire mesh. The cages were kept in a continuously lighted room and maintained at 25° C. Each group had its own feeder and water fountain. One group was medicated with 0.0125% amprolium (Amprol®, Merck & Co., Inc., Rahway, N.J.) in the feed ration. Another group received medicated feed with 0.0120% monensin (Coban-45®, Elanco Products Co., Indianapolis, Indiana) and a third group received .0970% sodium sulfamthazine (Sulmet®, American Cyanamid Co., Wayne, N.J.) in the drinking water. All drug concentrations used were manufacturer's suggested or officially approved for poultry. The fourth group served as a control and had no medicaton in the feed or water throughout the experiment. The fifth group served as a non-infected control and was neither infected nor received medication in the feed or water throughout the experiment.

Two days after initiation of medication, all birds, with the exception of the non-infected control group, were inoculated *per os* with 1 ml of sporulated oocyst inoculum containing an estimated 15,000 oocysts.

From Day 5 to Day 15 post inoculation (PI) the feces from each infected group was collected in drop pans. Oocyst production was determined by mixing the feces with 2.5% $K_2Cr_2O_7$, homogenizing the sample in a blender for 10 seconds, and measuring the volume in a graduated cylinder. Volumes were recorded and two samples were placed in labelled vials and stored in the refrigerator for determining parasite concentration later. The remaining fecal/$K_2Cr_2O_7$ mixture was discarded. After a count of oocysts per ml was determined in a McMaster's chamber, the daily oocyst discharge/bird was calculated. On Day 8 PI all medication was withdrawn and replaced thereafter with non-medicated game bird ration and tap water *ad libitum*. Mortality was monitored daily and *post mortems* were conducted to determined if death resulted from coccidial infection. Fecal samples from the nonmedicated noninfected control group were examined periodically for oocysts

during the experiment. Birds were weighed on Day 16 PI and compared to initial body weights to determine the average weight gains.

RESULTS

Coccidian Species Found

Two coccidian species were identified from the pooled litter samples obtained from the game farm. *Eimeria kofoidi* was the most prevalent, with 59% of the oocysts recovered and *Eimeria alectorae* represented 29.5% of the coccidial population. A third unidentified population of oocysts, believed to be a new species, totalled 11.5%.

Antibiotic Efficacy

Chukar partridges in the non-medicated infected group began passing oocysts on Day 5 PI (Fig. 1). By Day 6 PI, oocysts were present in the feces at a rate of over 12 million oocyst/bird. On day 7 PI, oocyst discharge peaked with 14 million oocyst/bird and then began to decline thereafter. Two of the five birds died of coccidial infection between Day 8 PI and Day 10 PI.

The amprolium medicated birds began passing oocysts on Day 5 PI and the oocyst output steadily increased until it peaked on Day 10 PI with 5 million oocysts/bird and then gradually decreased (Fig. 2). One bird died from coccidial infection on Day 11 PI. Although amprolium reduced the overall oocyst discharge compared to the nonmedicated infected group, it did not prevent mortality or morbitity (Table 1). Amprolium had no coccidiostatic effect on the parasites as indicated by a lack of a secondary peak in oocyst output after Day 8 PI when the medication was withdrawn from the feed ration.

In the monensin medicated group, oocysts were observed on Day 5 PI in relatively small numbers, but increased significantly on Day 6 PI and continued to be observed in the feces until the end of the collection period (Fig. 3). Like amprolium, monensin had no coccidiostatic effect on the parasite isolates and appeared to be less effective in reducing oocyst discharge compared to amprolium. There was no mortality in the monensin medicated group and there was no difference in weight gain compared to the nonmedicated noninfected control group.

Sulfamethazine medicated birds exhibited the most significant suppression of oocyst discharge. Yet, after the initial presence of oocyst in the feces on Day 10 PI, a significant number were observed on Days 13 and 14 PI (Fig. 4). Oocyst presence in the feces on Day 10 PI in high numbers suggests that sulfamethazine had primarily a coccidiostatic action on the parasites because once the medication was withdrawn on Day 8 PI, the infection was allowed to run its course in the host.

The nonmedicated noninfected control group did not pass any oocysts during the entire experiment. The monensin and sulfamethazine medicated groups had comparable weight gains to the nonmedicated noninfected control group (Table 1).

DISCUSSION

Although amprolium had some coccidiocidal action, by reducing the number of oocysts released, it did not reduce the coccidia sufficiently to prevent mortality. Amprolium was the only drug tested which failed to prevent mortality and the average weight gain of amprolium treated birds was poor compared to monensin and sulfamethazine medicated birds. Because of its extended and wide spread use, amprolium resistant strains of poultry coccidia are prevalent, and as a result, the drug is becoming obsolete (McDougald, 1982). It is apparent from this study that amprolium resistant chukar coccidia has developed as well. In fact, the game farm has routinely used amprolium medicated feed for their chukar flocks in the past.

Monensin is documented to be one of the most successful antibiotics in controlling morbidity and mortality in domestic poultry. Research results suggest that monensin does not effect the sporulation of the oocysts passed by the birds infected with eimerian parasites, but does reduce the pathogenic effects caused by oocyst production. (Joyner and Norton, 1977). When compared to amprolium and the nonmedicated infected group, it appears that monensin is effective in controlling mortality and maintaining good weight gain in chukars by effectively reducing the pathogenicity of the coccidia.

The significant suppression of chukar coccidia by sulfamethazine (Sulmet®) coupled with its water solubility are attractive characteristics for its use in chukar operations. Judging from the coccidiostatic activity of sulfamethazine after the drug was withdrawn from the drinking water, it appears that sulfamethazine interferes with the life cycle of *Eimeria* as early as the first schizontic generation, no later than the second, and suppressed the ultimate formation and discharge of oocysts. However, once medication is removed from the water supply the life cycle resumes at the point of suppression. While sulfamethazine did appear to have some depression of weight gains, perhaps due to drug toxicity, it was not an appreciable amount when compared to the nonmedicated infected and amprolium medicated birds. However, drug toxicity in poultry from prolonged use or administration of high dosages (Joyner et al, 1963) requires the prudent use of sulfamethazine.

ACKNOWLEDGMENTS

The authors thank Mr. Gary Hartke, the owner of the game farm, for suppling the birds for the experiment and access to his farm to isolate the parasites. We also thank Stacey Hart and Tim Miller for conducting pilot studies related to this research project. We appreciate the James Millikin Scholars Program at Millikin University for funding the project.

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Figure 1. Average daily oocyst discharge of three week old chukar partridges inoculated with a culture of *Eimeria* parasites previously isolated from a game farm.

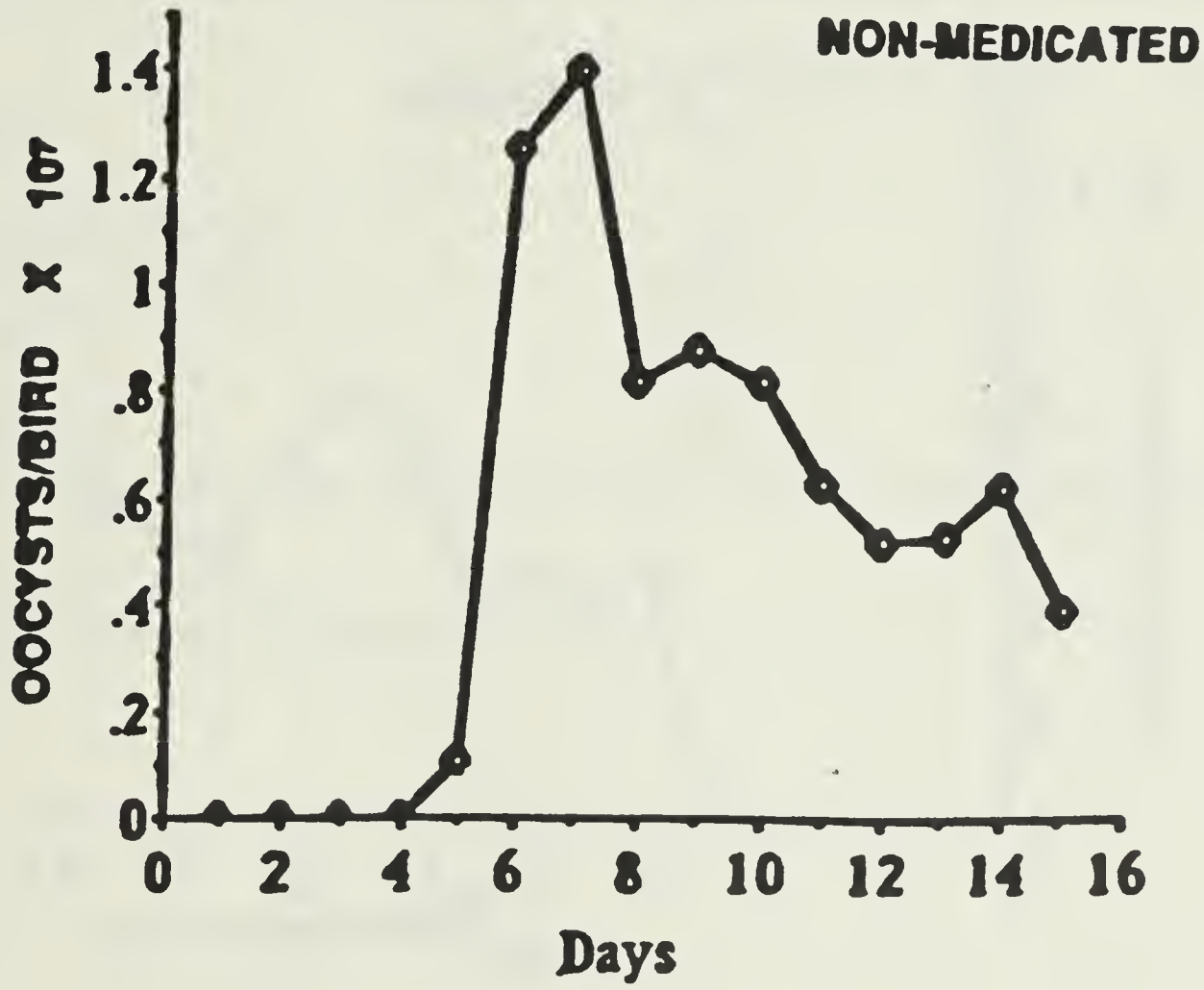

Figure 2. Average daily oocyst discharge of amprolium medicated, three week old chukar partridges inoculated with a culture of *Eimeria* parasites previously isolated from a game farm.

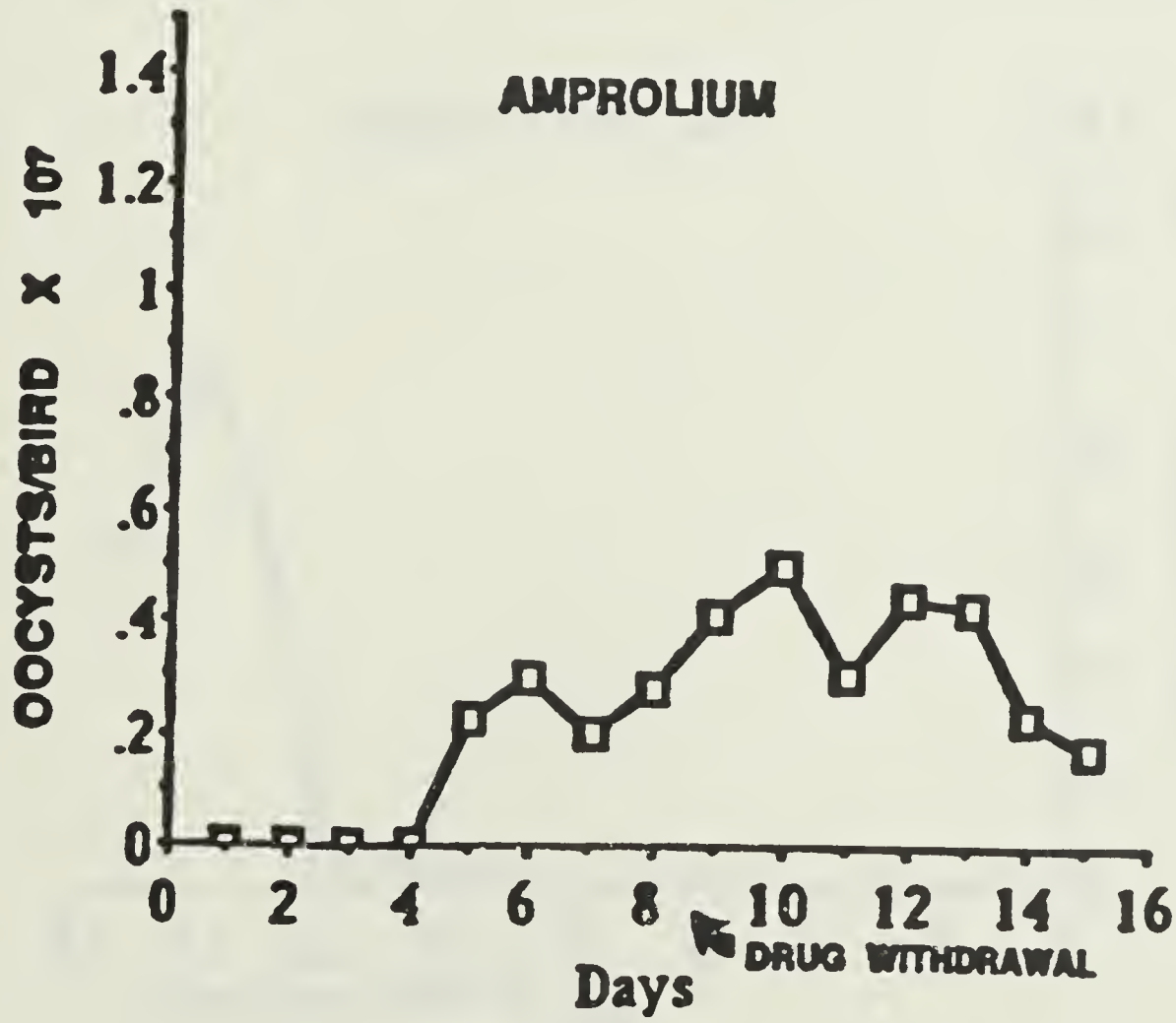

Figure 3. Average daily oocyst discharge of monensin medicated, three week old chukar partridges inoculated with a culture of *Eimeria* parasites previously isolated from a game farm.

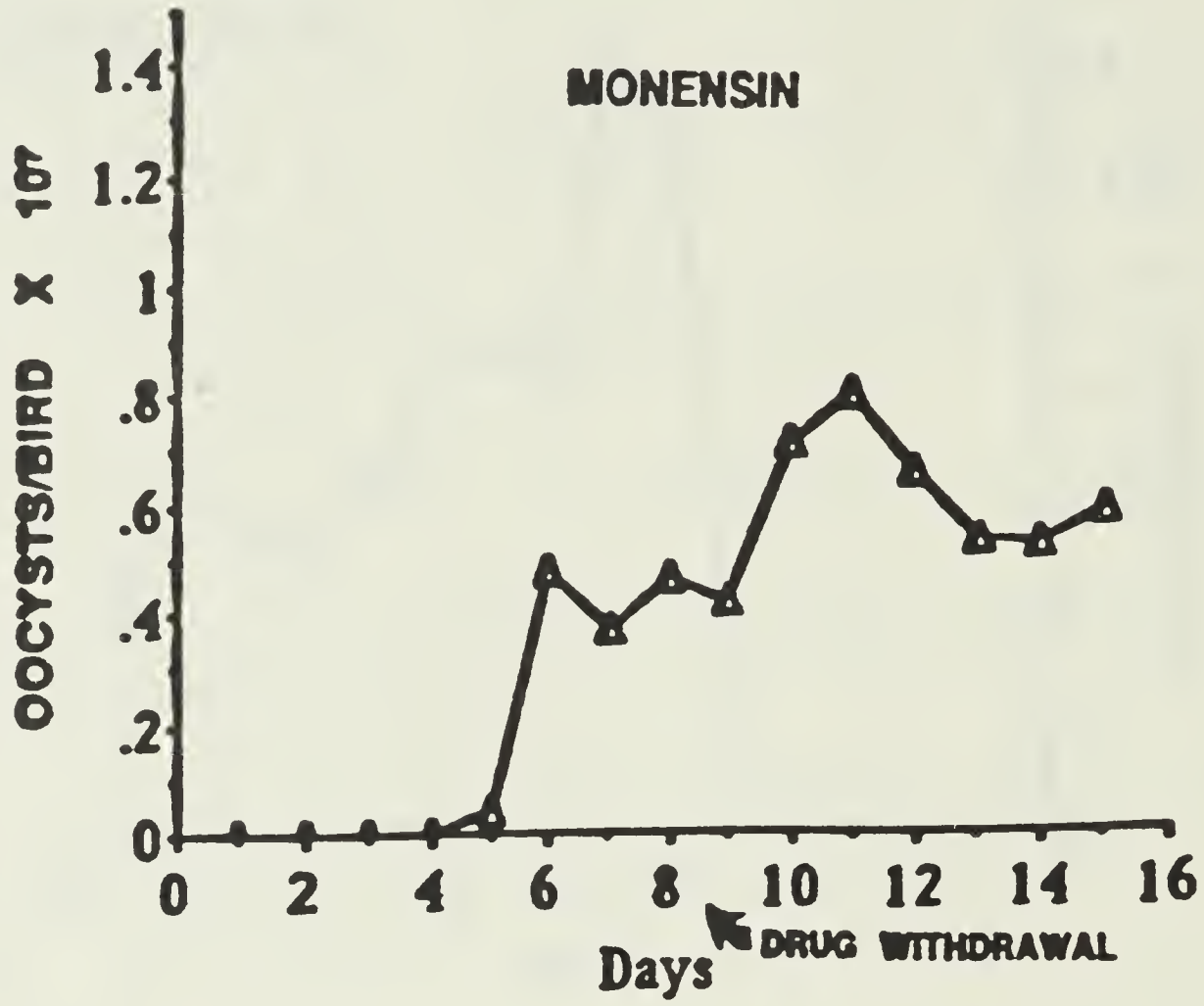

Figure 4. Average daily oocyst discharge of sulfamethazine medicated, three week old chukar partridges inoculated with a culture of *Eimeria* parasites previously isolated from a game farm.

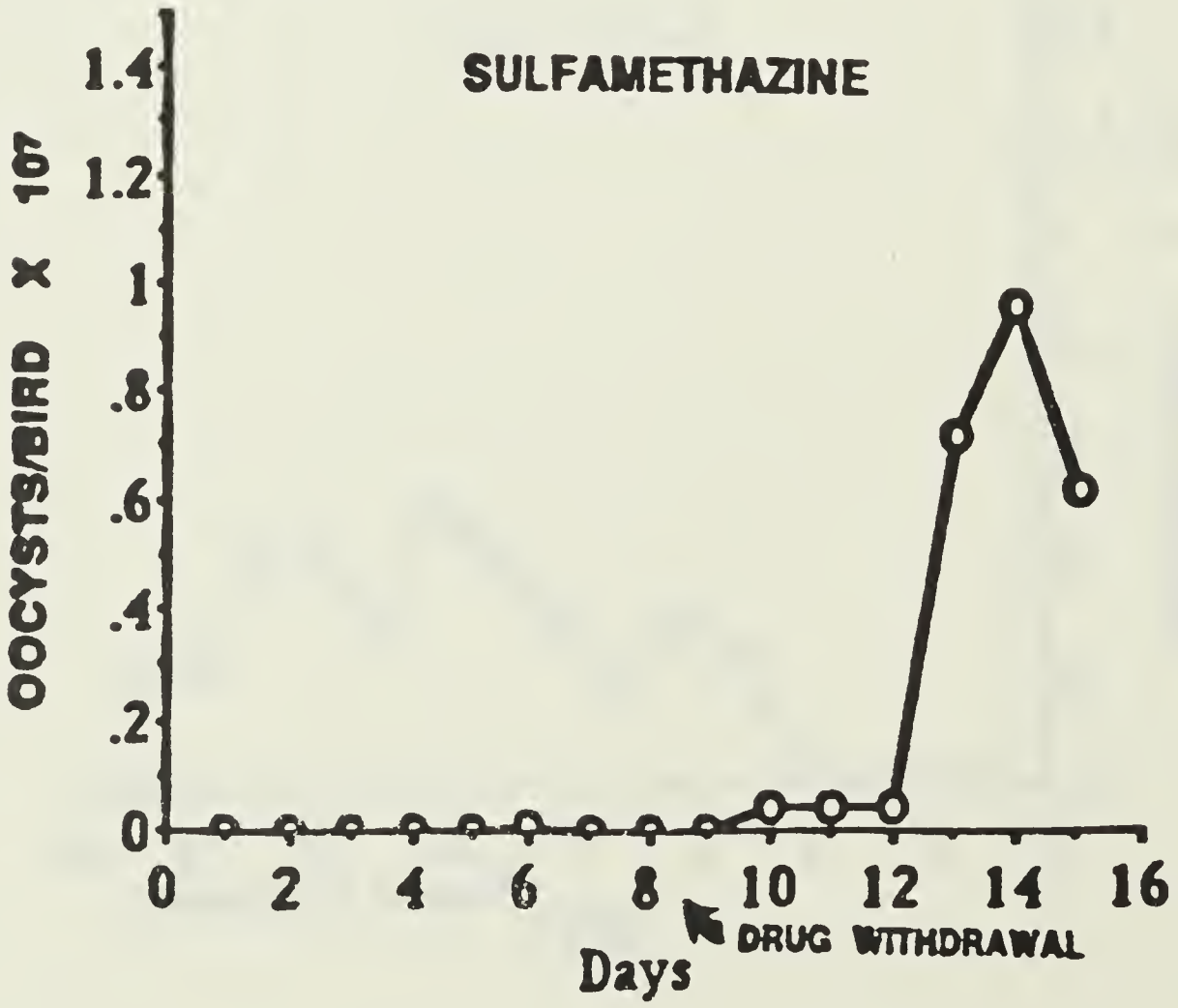

Table 1. Average body weights and weight gains of chukar partridges medicated at 3 weeks of age and infected with coccidia.

Treatment[A]	Average body wt. (gms.) Initial	Final	Weight gain (gms.)
Nonmedicated, uninfected	128.8	241.2	112.4
Nonmedicated, infected [B]	134.4	206.0	71.6
Amprolium [B]	141.2	219.0	77.8
Monensin	137.6	241.8	104.2
Sulfamethazine	134.2	226.6	92.4

[A] Five birds in each group.
[B] Averages do not include dead birds.

Transactions of the Illinois State Academy of Science
(1994), Volume 87, 1 and 2, pp. 61 - 70

The Conservation Reserve Program and Northern Bobwhite Population Trends in Illinois

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ABSTRACT

We examined 3 indexes of Northern Bobwhite abundance in Illinois at various geographic scales to determine possible relationships with the Conservation Reserve Program. Over 256,000 ha were enrolled in the CRP during the first 9 signup periods (1986-1990). About 87% of this land was in CP-1 vegetation (introduced cool-season grasses and legumes). Male bobwhite call counts in some parts of the state may have been positively related to amounts of CRP land. However, there was no strong evidence that autumn population densities increased as a result of the program. Positive CRP effects on local bobwhite habitat in some areas were probably offset by neutral or negative effects in others. We discuss possible reasons why potential benefits of the CRP for Northern Bobwhite have not been fully realized.
Key words: Conservation Reserve Program, Northern Bobwhite, populations, Illinois.

INTRODUCTION

The Conservation Reserve Program (CRP) of the 1985 Food Security Act encouraged landowners to convert highly erodible cropland to permanent cover (principally grasses) for a minimum of 10 years. From 1986 through 1989, approximately 13.7 million hectares (33.9 million acres) in the United States were enrolled in the program. This represented 8% of the nation's cropland (Bjerke 1991). Although the CRP was primarily intended to reduce soil erosion and grain surpluses, potential benefits for wildlife were widely anticipated (Farmer et al. 1988, Jahn 1988, Isaacs and Howell 1988, Schenck and Williamson 1991).

Among the species expected to benefit from the CRP was the Northern Bobwhite (*Colinus virginianus*) (Burger et al. 1990, Stauffer et al. 1990). Over the past 25-30 years, bobwhite have declined in abundance in Illinois and elsewhere, primarily because of intensified agricultural land use (Klimstra 1982, Brennan 1991). Realistically, large-scale

reversal of this trend can only come about adjunctly to agricultural programs and policies. It is important, therefore, to maximize opportunities offered by land diversion programs such as the CRP. Our objective was to compare CRP participation in Illinois with bobwhite population trends at various spatial scales (local, regional, and statewide). We sought information that would enhance the contribution of future farm programs to bobwhite and other upland wildlife.

STUDY AREAS

For regional analysis, we divided Illinois into 4 areas (South, Southcentral, Westcentral, and Northeast) using criteria of prevailing climate, land use, and estimated bobwhite densities (State of Illinois 1958, 1960) (Fig. 1). Bobwhites are scarce in the Northeast region because of unfavorable climatic and land-use conditions; therefore, we emphasized only the South, Southcentral, and Westcentral regions. We ranked individual counties (n = 56) across all regions according to proportion of CRP land and grouped them into 3 classes (LOW, MID, HIGH) representing the lower, middle, and upper 33 percentiles. Because of smaller sample sizes, counties within each region were divided into only 2 groups: upper 50 percentile (ABOVE) and lower 50 percentile (BELOW).

METHODS

We used 3 indexes of bobwhite abundance: estimated annual hunter harvest per km^2 (HPA), estimated harvest/hunter trip (HPT), and time/area counts of male bobwhite calls in early summer (MBC). Harvest data were obtained annually (1974-1991) by the Illinois Department of Conservation (IDOC) from post-season questionnaires mailed to a random sample of resident hunting license holders (Anderson and Campbell 1991:1-2). Male bobwhite whistle counts were recorded by IDOC biologists annually (1975-1991) along 46 semi-permanent routes located throughout the South, Southcentral, and Westcentral regions of Illinois. The 32-km transects consisted of 19-20 stops at about 1.6-km intervals. Each route was driven once per year in June on calm (wind <16 kph), relatively clear (<75% cloud cover) mornings and number of male bobwhite calls heard during a 2-minute listening period was recorded at each stop.

We obtained CRP areal enrollment by county and signup period (1-9; 1986-1989) from Agricultural Stabilization and Conservation Service (ASCS) records. Locations of individual CRP fields within 1.6 km of each call-count route were obtained from ASCS offices, recorded on 1:12,600 scale black and white aerial photographs, and later digitized using the Map and Image Processing System (MIPS, Miller et al. 1989). We determined proportion of CRP land in the various Conservation Practices (CP 1-14) from Soil Conservation Service (SCS) data.

We performed repeated measures Analysis of Variance (ANOVA) using PROC GLM (SAS Institute Inc. 1985:433-506). We used CONTRAST statements to test the hypothesis that linear trends in HPT, HPA, and MBC over time (1985-1991) did not differ among counties grouped according to relative amounts of CRP land ($\alpha = 0.10$). LOW, MID, and HIGH groups were compared at the statewide level and ABOVE and BELOW groups at the regional level. For statewide and regional analyses, groupings were based on county-wide amounts of CRP land. For analysis of MBC at the local

level, groupings were based on relative amounts of CRP land within 1.6 km of each call route (3.2-km wide corridors) and within 0.4 km of each listening stop (0.8-km diameter circles).

RESULTS

CRP Participation

Approximately 256,260 ha in Illinois (1.8%) were enrolled in the CRP during the first 9 signup periods (1986-1990). Areal representation in the South, Southcentral, Westcentral, and Northeast regions was 4.0, 2.7, 2.3, and 1.0%, respectively (Table 1). Twenty four (42.9%) of 56 counties in the 3 primary quail regions contained 0.1-1.8% CRP land, 27 (48.2%) contained 2.1-5.3%, and 5 (8.9%) had 8.0-9.0%. This latter group included Hamilton, Jefferson, and Franklin counties in the Southcentral region and Union and Johnson counties in the South region. Based on timing of and response to signups 1-9, we estimated percentage of total CRP land extant during the 1985-1991 growing seasons as 0, 5, 29, 57, 80, 100, and 100%, respectively.

Nearly 87% of the state's CRP land was under CP-1 contract (introduced cool-season grasses and legumes), ranging from 80.0% in the Northeast to 92.2% in the Southcentral region (Table 1). CP-1 plantings varied widely among counties, apparently reflecting different recommendations by local ASCS and SCS offices. For example, the adjacent counties of Hamilton and Jefferson had about 96% of their >23,000 ha of CRP land in CP-1 contracts. In Jefferson County, >94% of CP-1 land was planted to timothy (*Phleum pratense*)-redtop (*Agrostis alba*)-Korean lespedeza (*Lespedeza stipulacea*), whereas tall fescue (*Festuca arundinaceae*) was the predominant (78%) CP-1 planting in Hamilton County (David et al. 1992).

Bobwhite Population Trends

Statewide. -- Temporal trends (1974-1991) for the 3 indexes of bobwhite abundance (HPT, HPA, and MBC) were relatively similar at the statewide level (Fig. 2). Each declined precipitously in the late 1970's, primarily from 3 consecutive severe winters (Roseberry and Klimstra 1984:212). Recovery began in the early 1980's, and by the end of the decade HPT and MBC had regained or exceeded former levels but HPA had not, probably due in part to reduced numbers of quail hunters (Roseberry and David 1992).

During the period 1985-1991, counties grouped according to amount of CRP land (LOW, MID, HIGH) showed similar trends in MBC ($P = 0.443$) and HPT ($P = 0.195$). There was, however, a negative CRP effect on HPA ($P = 0.021$), i.e., total harvest declined most in counties with the most CRP land.

Regional. -- In the South region, temporal trends in MBC, HPT, and HPA did not differ between ABOVE and BELOW groups ($P = 0.177$, 0.129, and 0.724, respectively). ABOVE and BELOW groups in the Southcentral region did not differ for MBC ($P = 0.560$) or HPT ($P = 0.591$), but total harvest (HPA) declined most in counties with the most CRP land ($P = 0.002$). In the Westcentral region, ABOVE and BELOW counties had similar trends in HPT ($P = 0.631$) and HPA ($P = 0.841$), but increases in MBC were more pronounced in the ABOVE group than in the BELOW group ($P < 0.001$).

Local. -- Group memberships based on amount of CRP land within 1.6 km of the route and 0.4 km of each listening stop were similar to those based on county-wide totals, hence results were similar to those reported above. The only detectable CRP effect was in the Westcentral region where call count trends over time differed between groups with above- and below-average amounts of CRP land within 1.6 km of the route (P = 0.058).

DISCUSSION

With the possible exception of call counts in the Westcentral region, our study provided no conclusive or consistent evidence that the CRP had a measurable effect on bobwhite population trends in Illinois through 1991. This may have been because (1) our study design and/or data were not adequate to demonstrate a CRP effect, or (2) a CRP effect did not exist. If we reject the former and accept the latter, then there may have been 1 or more possible reasons.

Habitat modeling (Roseberry et al. 1992:17) suggested that CRP fields may have little potential impact on bobwhite habitat if they comprise <6% of the total land area. At the time of our study, only 5 of Illinois' 102 counties contained >6% CRP land and the 3 primary quail regions totalled <3%. Currently (through signup 12), 9 counties in Illinois have >6% CRP, but 84 still have <4%. It is perhaps unrealistic, therefore, to assume the CRP could have exerted a major impact on bobwhite abundance at the regional or statewide level given the relatively small amount of land involved.

Even in areas with considerable CRP land, suitability of individual fields likely varied spatially so that beneficial effects in some localities were offset by neutral or negative effects in others. Roseberry et al. (1992:9) concluded that CRP contribution to local bobwhite habitat would depend on: "a) the amount of CRP land present, b) its suitability for bobwhite use, c) the suitability of replaced and remaining cropland for bobwhite use, d) the juxtaposition of CRP fields with other habitat components, and e) the composition and quality of existing bobwhite habitat, in particular the limiting factors."

During our study, >93% of the CRP land was planted to grass or a grass-legume mix and would therefore be potentially useful to bobwhite primarily as nesting, brood rearing, or roosting cover. Thus, even though individual CRP fields might receive considerable seasonal use by bobwhite, total population densities would not necessarily be increased in areas where food or protective cover were limiting. In fact, overall habitat suitability might be reduced if replaced cropland had been an essential food source. Even where nesting or brood rearing habitat was limiting, addition of CRP land might not have been beneficial because of unsuitable vegetation or excessive or untimely disturbance such as summer mowing.

Burger et al. (1990) suggested that CP-2 (warm-season grasses) and CP-4 (wildlife habitat) fields were superior to CP-1 vegetation (cool-season grasses and legumes) for bobwhite. However, the latter CP was the prevailing choice of CRP participants in Illinois, probably reflecting relative cost of seed, availability of equipment, familiarity, and recommendations from agricultural advisors (David et al. 1992). Only 3.5% of the CRP land in Illinois was committed to CP-2 or CP-4 with 86.9% going into CP-1. The latter commonly featured tall fescue, orchard grass (*Dactylis glomerata*), or orchard grass-

legume mixes (David et al. 1992), which is of fair to poor suitability for bobwhite nesting or brood rearing (Martin 1988).

Even when vegetative composition of CRP fields is potentially suitable for bobwhite, use often is severely limited by mowing. In northern Missouri, Burger et al. (1990:82) considered mowing a "major factor limiting habitat quality of CRP lands." As much as 40% of Illinois CRP fields may be subject to seasonal mowing (David et al. 1992). Mid-summer mowing may actually turn some CRP fields into ecological traps where nesting birds and/or broods are initially attracted, then either killed by mowing or forced into inferior habitat where mortality from other causes is increased.

Langner (1989:388) compared nationwide CRP enrollment to estimated amounts of existing habitat and concluded that the CRP had: ". . . little impact on total habitat availability, and therefore [resulted in] . . . few new entrants into the hunting population." Instead, she predicted that it would result in ". . . additional days of small game hunting from existing hunters." In Illinois, however, neither estimated number of quail hunters, nor their average days afield changed significantly during the period of potential CRP influence (1985-1991) (Roseberry and David 1992). As noted earlier, CRP actually seemed to have a negative impact on total bobwhite harvest in some parts of Illinois. Conceivably, bobwhite harvesting is less efficient in block cover provided by CRP fields than in linear hedgerow-fencerow cover adjacent to cropfields.

MANAGEMENT RECOMMENDATIONS

Brennan (1991:552) suggested that the CRP may have been a "lost opportunity" for enhancing Northern Bobwhite habitat because potential benefits were not fully realized. Merits of the CRP cannot, of course, be judged solely on its contribution to a single species. Other wildlife species and communities also must be considered along with the primary mission of reducing soil erosion and grain surpluses (Young and Osborn 1990). Nevertheless, we agree that the program could have benefited bobwhite much more than it apparently did in Illinois. Under certain circumstances, CRP lands undoubtedly contribute positively to local bobwhite habitat. In other situations, however, their effect may be neutral or even negative. This, coupled with the fact that CRP land comprises a relatively small proportion of the total habitat base, are thought to be the principal reasons why regional and statewide Illinois bobwhite population levels did not respond positively to the CRP, at least through 1991. In retrospect, we believe CRP value for bobwhite in Illinois would have been enhanced had there been: (1) less mowing, especially mid-summer mowing, (2) more weedy vegetation via strip discing and controlled burning, (3) more CP-2 and CP-4 plantings and less CP-1, especially tall fescue, and (4) more provision of food in the form of food plots or Korean lespedeza seedings.

Greater promotion and implementation of wildlife interests in future CRP or related conservation-agricultural programs will require action at the national, state, and local levels. Nationally, Cook (1989) suggested: improvement of contract features to enhance wildlife, targeting enrollment to areas of special significance for wildlife, and development of longer term retirement programs, probably involving conservation easements. At the state level, cost-sharing and other landowner incentives must be developed and

implemented to maximize opportunities for wildlife afforded by federal conservation-agricultural programs. Locally, there must be (1) greater awareness and cooperation among ASCS/SCS officials regarding wildlife interests (Miller and Bromley 1989), (2) more direct input from wildlife biologists regarding specific practices to benefit wildlife (e.g., White 1992), and (3) greater effort to inform and educate participating land owners regarding available cost/sharing opportunities (Kurzejeski et al. 1992).

The future of the CRP as it now exists is unclear. Contracts on the oldest fields will begin to expire in 1996 and significant area could be removed from the program by 1998. Fate of fields currently enrolled is uncertain, but many will likely be returned to cropland while others probably will be hayed or grazed (Carek 1988). In any event, it is probable that the area of relatively undisturbed perennial vegetation will be substantially reduced. For this reason, efforts should be directed toward maximizing potential contribution of these areas to wildlife. To do this, it is essential that juxtaposition of retired land to other cover types be considered (Langner 1989) and that specific management recommendations be cognizant of existing local and regional habitat conditions, especially components or life requisites that seem to be limiting (Roseberry et al. 1992).

ACKNOWLEDGMENTS

S. L. Etter and A. Woolf reviewed the manuscript and made helpful suggestions. Funding for this study was provided by the Illinois Department of Conservation through Federal Aid in Wildlife Restoration Projects W-106-R and W-99-R.

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Table 1. Regional and statewide CRP enrollment and major Conservation Practices in Illinois during signups 1-9 (1986-1989).

Region	Percent of Area in CRP	Percent of CRP land in				
		CP-1[a]	CP-2[b]	CP-3[c]	CP-4[d]	CP-10[e]
South	4.01	83.00	0.42	2.43	1.12	10.90
Southcentral	2.71	92.24	1.32	2.23	0.98	1.85
Westcentral	2.26	89.91	0.76	1.21	2.19	3.20
Northeast	0.96	79.95	2.01	4.01	4.47	7.77
Statewide	1.77	86.93	1.25	2.53	2.23	5.16

[a] Introduced grasses and legumes.
[b] Native grasses.
[c] Trees.
[d] Wildlife habitat.
[e] Already in grass.

Figure 1. Study regions of Illinois.

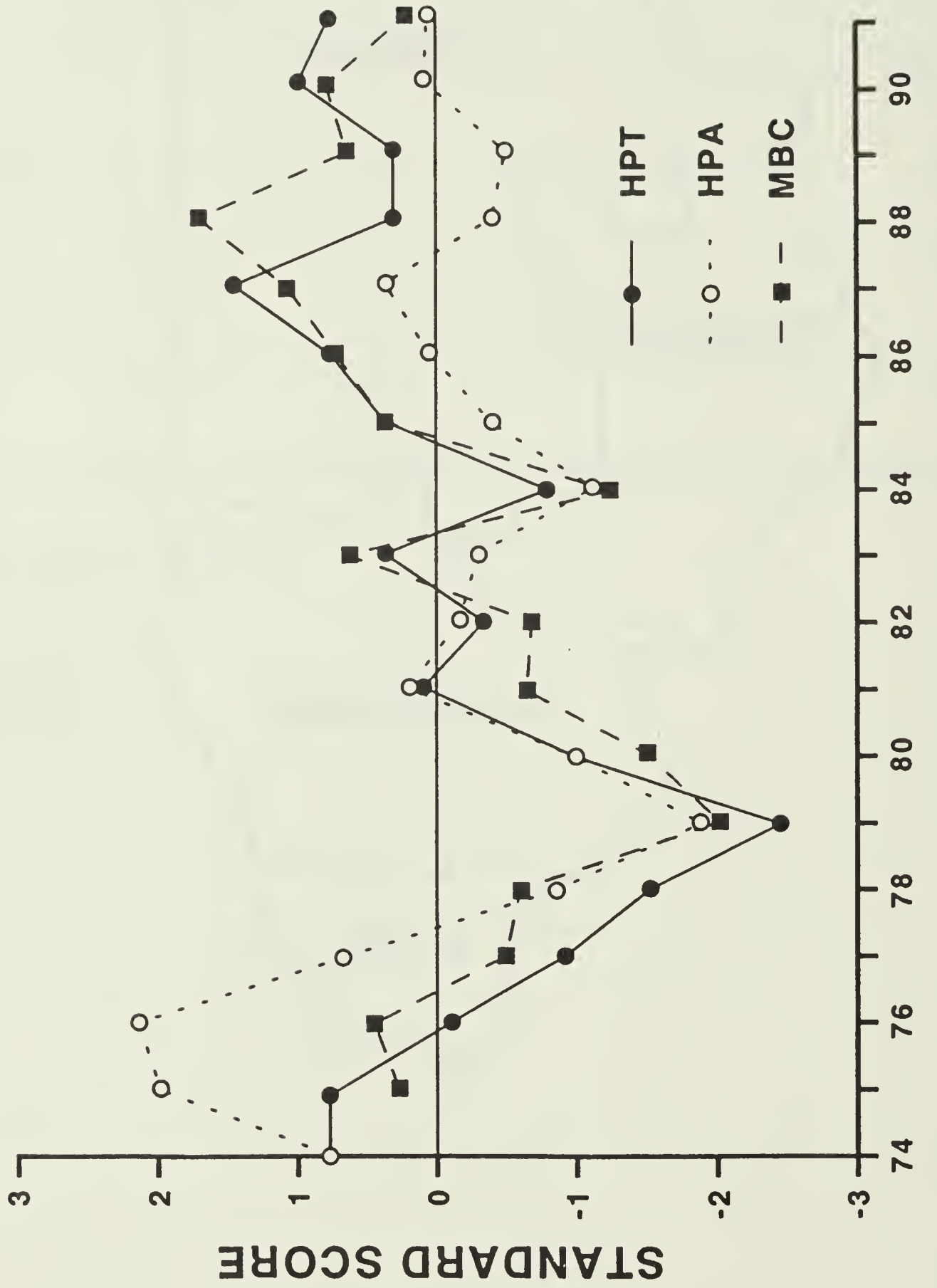

Figure 2. Trends in indexes of Illinois bobwhite abundance: harvest/hunter trip (HPT), harvest/area (HPA), and male whistling counts (MBC).

Transactions of the Illinois State Academy of Science
(1994), Volume 87, 1 and 2, pp. 71 - 82

Status and Distribution of Three Rare Illinois Fishes: Blacktail Shiner (*Cyprinella venusta*), Northern Starhead Topminnow (*Fundulus dispar*), and Cypress Darter (*Etheostoma proeliare*)

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ABSTRACT

The blacktail shiner (*Cyprinella venusta*), northern starhead topminnow (*Fundulus dispar*), and cypress darter (*Etheostoma proeliare*) are all species of special concern in Illinois. By compiling historical records from museums and sampling nearly all historical sites using standard collecting techniques, we conducted status surveys for these three species. Although the distribution of *E. proeliare* appears static, *F. dispar* has experienced a reduction in range due to human activities. The distribution of *C. venusta* is broader than previously documented; however, our sampling efforts and observations indicate low population levels.

INTRODUCTION

The blacktail shiner, *Cyprinella venusta* (Cyprinidae), northern starhead topminnow, *Fundulus dispar* (Fundulidae), and cypress darter, *Etheostoma proeliare* (Percidae), are small teleosts found in Illinois waters. Although not currently listed as threatened or endangered, all three species have been placed on the Watch List by the Illinois Endangered Species Technical Advisory Committee on Fishes (Burr 1991). While common in central portions of their North American ranges, these species recieve special status at the state level along their range boundries. We summarize the findings of status surveys conducted from April - August 1992 of these three rare Illinois species. We also provide explanations for their current distributional patterns.

METHODS

We visited and sampled virtually all known historical localities for *Cyprinella venusta*, *Fundulus dispar*, and *Etheostoma proeliare* within the state of Illinois during the spring

and summer of 1992. We compiled historical records by accessing museum records from the Southern Illinois University at Carbondale Ichthyological Collection (SIUC), the Illinois Natural History Survey Fish Collection (INHS), and the University of Michigan Museum of Zoology Fish Division (UMMZ). In addition to historical localities we sampled several new locations in an effort to document the presence of these species at new sites. We deposited all voucher specimens at SIUC. All sites were sampled using a standard 3.1 m minnow seine and/or 9.3 m bag seine with 4.8 mm mesh. A minimum of 0.75 hrs of collecting effort was expended at each site. Physical characteristics such as stream width, depth, current, substrate, and water clarity were recorded at each site along with the condition of the terrestrial habitat surrounding the site. Appendix 1 lists all sites at which we collected the three species.

RESULTS AND DISCUSSION

BLACKTAIL SHINER, *Cyprinella venusta*

Cyprinella venusta is one of 27 described species in the genus *Cyprinella* (Mayden 1989), four of which occur in Illinois. The species generally occupies sand-bottomed pools and runs of small to medium sized streams, with upland populations occurring over substrates with more gravel and rubble in pools and runs (Page and Burr 1991).

Cyprinella venusta occurs from the Rio Grande drainage of Texas, east to the Suwannee River drainage, Georgia and Florida, and in the Mississippi River drainage (mostly in the Mississippi Embayment) from southern Illinois to Louisiana (Gilbert and Burgess 1980, Page and Burr 1991). In Illinois, Smith (1979) reported the species only from the Clear Creek drainage of extreme southwestern Illinois and from two locations on the Ohio River. Records at the UMMZ from the late 1930s to early 1940s indicate that *C. venusta* also was found in the lower Big Muddy River and the Cache River near its mouth.

We collected and verified *C. venusta* from four of 10 historical locations (Fig. 1). This suggests that *C. venusta* has probably disappeared from the Big Muddy River drainage but continues to persist in the Cache River, Orchard Creek, and Clear Creek drainages of southern Illinois. The collection of a few individuals from four sites in three separate drainages demonstrates that the species is somewhat more widespread than previously thought (Smith 1979). However, low numbers of individuals collected may reflect small population sizes.

A single historical record is known from the Big Muddy River at Rattlesnake Ferry (Fig. 1). This and several other sites on the lower Big Muddy have been sampled intensively over the past 30 years; all failed to produce *C. venusta*. In addition, this is the northernmost record for the species, and the individual captured in 1940 may represent a waif. Although suitable habitat exists at this site, it seems doubtful that a sizable population of this species has existed here in the past 30 years.

The two Ohio River records for *C. venusta* are represented by single specimens and also are probable waifs. The habitat at these sites is of marginal quality for the species. Most records come from much smaller streams where nearly all reproduction probably takes place. The extensive electrofishing and seining surveys of the lower Ohio River by the Ohio River Valley Water Sanitation Commission, the SIUC Fisheries Research

Laboratory, and several consulting firms have not revealed any recent records of *C. venusta*.

In the Cache River drainage, we found the species at one of two known historic sites. The lower Cache River has suffered historically from excessive erosion and high siltation rates. Much of the mainstem has been channelized and some of the flow has been shunted artificially back to the Ohio River through the Post-Creek Cutoff. Recent surveys of 25 Cache River stations by Illinois Department of Conservation stream biologists and at 19 stations by SIUC biologists (Phillippi et al. 1986) did not reveal *C. venusta*. We presume that the species is rare in the drainage and only occurs in the extreme lower reaches.

Cyprinella venusta has been collected twice (1982 and 1992) from Orchard Creek, a small, direct tributary of the Mississippi River. Habitat quality is marginal as judged from the soft mud substrate and lack of obvious spawning sites (e.g., crevices under bark on logs, between large rocks, etc. [Heins 1990]). Because of the lack of spawning substrate it seems unlikely that a breeding population exists here.

The Clear Creek system has historically been a consistently productive stream for *C. venusta* in Illinois. Records from the drainage date from 1881 to present, indicating that breeding populations almost certainly occur within this drainage. Permanent flow, firm gravel substrates, and available spawning sites are habitat qualities that have undoubtedly contributed to the success of the species in the drainage.

Cyprinella venusta is known to frequently hybridize with the red shiner, *C. lutrensis*, in both the laboratory and in nature (Hubbs and Strawn 1956). Both Clear Creek collections made during our 1992 survey contained individuals intermediate between *C. venusta* and *C. lutrensis*. Alteration of stream conditions has been considered a major factor in the breakdown of reproductive isolating mechanisms and the subsequent production of introgressive hybrids (Hubbs and Strawn 1956). The various habitat changes in Clear Creek (e.g., stream channelization, excessive gravel removel and concomitant removal of instream cover, denuding of banks resulting in high summer stream temperatures, and siltation) have produced conditions favorable for the ecologically labile *C. lutrensis* (Matthews and Hill 1977) and may have elevated rates of hybridization between the two species.

NORTHERN STARHEAD TOPMINNOW, *Fundulus dispar*

The northern starhead topminnow is one of 27 recognized species in the genus *Fundulus* (Fundulidae), five of which occur in Illinois. Primarily a surface dweller, this species is found in lowland lakes, swamps, sloughs, and quiet backwaters of streams and rivers. *Fundulus dispar* occurs in the central Mississippi River drainage from the Ouachita River drainage, Louisiana, north to the Wisconsin River drainage, Wisconsin, and east to the headwaters of the Kankakee River drainage, Indiana (Wiley 1980, Page and Burr 1991). Within Illinois, Smith (1979) described the distribution of *F. dispar* as extremely sporadic, with records from the Fox River Chain of Lakes, Pecatonica, Kankakee, central and lower Illinois, and lower Wabash river drainages and the LaRue-Pine Hills Ecological Area/Big Muddy River drainage.

We collected and verified *Fundulus dispar* from only four of 23 historical locations, and at one site not known previously to harbor the species (Fig. 2). We therefore conclude that the species' range has been significantly reduced since the time of Smith's (1979) statewide survey, conducted from 1950-1978.

We collected *F. dispar* at two of seven lakes in the Fox River Chain of Lakes where the species was known to occur, and observed large numbers of individuals at both sites. Since this species inhabits quiet, sheltered areas and spawns in aquatic vegetation (Taylor 1993), extensive residential development of shorelines and removal of aquatic vegetation has had the greatest negative effect on *F. dispar* in this area. If present urbanization trends continue, this species will likely experience additional declines in population size and distribution.

In the Pecatonica River drainage in Illinois, one historical record exists for *F. dispar* from the Sugar River, Winnebago County. We did not find *Fundulus dispar* at this site, but collected two individuals in nearby Racoon Creek, a new record for the species in the Pecatonica River drainage. These two collections presumably represent remnants of a once larger population. Extensive agricultural land use, resulting in high sediment loads in streams, have reduced the amount and quality of habitat available for *F. dispar* in this drainage.

No *F. dispar* were collected in the Kankakee River drainage during our survey. Five historical locations in this drainage were sampled. In addition to our efforts, the U. S. Geological Survey sampled nine other sites in the Kankakee River drainage during their 1990 survey of the upper Illinois River Basin, but failed to collect *F. dispar* (Warren 1991). A single specimen collected in 1989 from the Kankakee River mainstem in Will County suggests that small populations still exist within the drainage. Continued residential development along shorelines and high nutrient and siltation loads (IEPA 1990) have likely contributed to loss of habitat for this species.

In the central and lower Illinois River drainage, *F. dispar* was collected at one of 10 historical locations. Several recent collections at this site (Fig. 2) indicate that this a stable population. Since all Illinois River mainstem locations predate 1900, we believe these populations have been extirpated as a result of excessive channelization, loss of vegetation, siltation, and water level manipulation (Mills et al. 1966). Two records dating 1967 and 1972 from sloughs along the lower Illinois River (Calhoun and Jersey Cos.) suggest that populations may still occur in this portion of the drainage.

The LaRue-Pine Hills Ecological Area supports the largest and most stable population known in Illinois, as evidenced by numerous historical records and observations made during our survey. The Ecological Area, a 808 hectare section of the Shawnee National Forest, is comprised mostly of bottomland swamp occupying an old channel of the Big Muddy River. Because this area is under the protection of the U. S. Forest Service as a Research Natural Area, the continued existence of this population seems assured.

Forbes and Richardson (1908) reported *F. dispar* from five localities along the lower Wabash River drainage below the mouth of the Embarras River. Since all records predate 1900 and a recent and extensive survey of the wetlands of the lower Wabash and Ohio

Rivers (Burr and Warren 1987) failed to reveal the presence of *F. dispar*, we omitted this area from our field work. Smith (1979) also failed to find the species in these drainages during his statewide survey and listed oil pollution and drainage of floodplain swamp habitats as reasons for its disappearance. We presume the species has been extirpated in this portion of its range.

CYPRESS DARTER, *Etheostoma proeliare*

The cypress darter, *Etheostoma proeliare*, one of 20 species of *Etheostoma* in Illinois, is one of the smallest species of darters. It has an affinity for protective cover such as leaves, vegetation, sticks, and exposed tree roots along undercut banks of small to large streams and the margins of lowland creeks, swamps, and sloughs (Burr 1978).

Primarily a Coastal Plain species, this fish occurs east to the Choctawhatchee River, Florida, southwest to the San Jacinto River, Texas, and north through lowland areas to the Big Muddy River, Illinois (Burr 1978). In Illinois, *E. proeliare* is known from only a few localities in the extreme southern part of the state (Burr 1978, Smith 1979).

Our field work resulted in the collection and verification of *E. proeliare* from eight of 15 known historical locations, and two sites not known previously to harbor the species (Fig 3). In addition, Illinois Department of Conservation stream biologists collected *E. proeliare* at two previously unrecorded sites in the Cache River drainage during the spring of 1992. Our results suggest that *E. proeliare* has probably disappeared from the Big Muddy and Wabash River drainages, but continues to persist, sometimes commonly, in both the Cache River and Bay Creek drainages of southern Illinois. Collection of individuals from 12 sites demonstrates that the species is nearly as common as it was during the time of Smith's (1979) surveys (Fig. 3). Since we did not voucher all individuals encountered, numbers of individuals reported do not nessesarily reflect population levels for this species.

Within the Big Muddy River drainage three historical records are known from Kincaid Creek prior to its impoundment in 1970 to create Kincaid Lake. Kincaid Creek is now greatly altered below the dam and consists of a narrow, deep, meandering channel subject to over-flow from the dam. Steep banks and deep water make the creek difficult to sample and a lack of sufficient instream cover provides little suitable habitat for *E. proeliare*. Two of the historical locations (from 1937 and 1939) are now part of the Kincaid Lake impoundment, and it is unlikely that the species survives in the lake. Our sampling at the remaining site below the dam failed to reveal *E. proeliare*.

Of six historical locations known from the Bay Creek-Ohio River drainage we found *E. proeliare* at five sites and at one site previously unreported. Stream channelization, impoundment, and siltation pose the greatest threats to *E. proeliare* in this area. Shaded streams in this drainage with riparian buffer zones, spring seeps, and accumulated instream cover seem to provide optimum habitat and offer the best sites for continued existence of the species in Illinois.

Of six historical locations within the Cache River drainage, we found the species at three sites and three additional sites previously unreported. The new sites were all geographically close to historical sites and do not result in a dramatic range extension for

the species. The threats to *E. proeliare* habitat in this drainage mirror those from the Bay Creek drainage. As previously mentioned, the lower Cache River appears to have suffered historically from excessive erosion and consequently has greater siltation rates. In addition, more of the Cache watershed where *E. proeliare* is known to occur has been developed as crop or pastureland than that of Bay Creek.

A literature record exists for *E. proeliare* (as *Microperca punctulata*) from the Skillet Fork (Wabash River), Wayne County (Large 1903). Voucher specimens could not be located for this collection (Burr 1978), and we did not visit the site during this survey since there have been no subsequent records for the drainage.

CONCLUSIONS

The conservation status of *E. proeliare* throughout its Illinois range appears to be stable, with most known historical populations extant. However, stream channelization and an impoundment have contributed to the extripation of at least one drainage population (Big Muddy River). *Fundulus dispar* has experienced a dramatic reduction in range over the past 15 years. Loss of habitat due to stream channelization, drainage of wetlands, and clearing for development are the most likely causes. Although the distribution of *C. venusta* in Illinois has remained fairly static, numbers of individuals captured were low. This may be due, in part, because Illinois populations of *C. venusta* are on the northern edge of their range and are somewhat isolated from a stable source pool, resulting in poor recruitment.

The apparent extirpation of *F. dispar* from a significant portion of its Illinois range warrants reconsideration of its conservation status. We recommend that the species be elevated from the Watch List category to endangered in Illinois. The extirpation of the Big Muddy River population of *E. proeliare* and its persistence at a number of localities restricted to southern Illinois indicate that it should remain on the Watch List for further monitoring. The small Illinois range, precariously low numbers of individuals, and evidence of continued hybridization with *C. lutrensis* suggests that *C. venusta* should be elevated from the Watch List to threatened in Illinois. A study of the extent of hybridization between *C. lutrensis* and *C. venusta* would provide for a more informed decision regarding the genetic "purity" and conservation status of the Illinois populations of *C. venusta*.

ACKNOWLEDGMENTS

We wish to thank Kevin S. Cummings, Lawrence M. Page, and Christine A. Mayer of the Center for Biodiversity, INHS, for providing us with a list of Illinois collection records from the INHS Fish Collection. Randy A. Sauer, Illinois Department of Conservation, provided information about sites he sampled recently in the Cache River drainage. We are grateful to Randy for depositing his valuable fish collections at SIUC. Douglas W. Nelson, UMMZ, provided information on early records of *C. venusta* in Illinois. We are especially grateful to Brett J. Dunn and the SIUC Spring-Term ichthyology class for assistance in the field. Regina J. Paul assisted with sorting, cataloguing, and curating the approximately 50 fish collections made for this survey. Funding was provided by the Illinois Department of Conservation.

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Appendix 1. Sites at which *Cyprinella venusta*, *Fundulus dispar*, and *Etheostoma proeliare* were collected during 1992. Number of specimens vouchered and SIUC catalog number are indicated in parentheses. An asterisk indicates previously unpublished locality.

Blacktail Shiner, *Cyprinella venusta*

Mississippi River drainage

* Site 1. Alexander Co., Orchard Creek at old R.R. overpass, 2.8 km S of Thebes, T29N, R3W, Sec. 21 (3, SIUC 19452).

Site. 2. Union Co., Clear Creek , 3.2 km E Reynoldsville, T13S, R2W, Sec. 20 (3, SIUC 19468).

Site 3. Alexander Co., Clear Creek, 3.2 km E. McClure, T14S, R3W, Sec. 1 (2, SIUC 19954).

Ohio River drainage

Site 4. Alexander/Pulaski Co., Cache River just E of jct. Hwy. 3 and Hwy. 127, T16S, R16E, Sec. 12 (1, SIUC 19964).

Northern Starhead Topminnow, *Fundulus dispar*

Illinois River drainage

Site 1. Mason Co., Crane Creek at Co. Rd. 1200N, 3.2 km W Easton, T21N, R7W, Sec. 27 (4, SIUC 19772).

Fox River Chain of Lakes

Site 2. Lake Co., East Loon Lake 2.4 km N town of Lake Villa, T46N, R10E, Sec. 21 (3, SIUC 19777).

Site 3. Lake Co., Little Silver Lake just E of Antioch, T46N, R10E, Sec. 16 (3, SIUC 19760).

Pecatonica River drainage

* Site 4. Winnebago Co., Racoon Creek at Yale Bridge Rd., 6.4 km WNW Rockton, T46N, R1E, Sec. 8 (2, SIUC 19787).

Clear Cr.-Mississippi River drainage

Site 5. Union Co., La Rue-Pine Hills Ecological Area, T11S, R3W, Sec. 21 (3, SIUC 21687).

Cypress Darter, *Etheostoma proeliare*

Bay Cr.-Ohio River drainage

Site 1. Johnson Co., Max Creek at Hwy. 127, 4 km SW Simpson, T12S, R4E, Sec. 19 (4, SIUC 19409).

Site 2. Johnson Co., Max Creek at Cedar Lake Rd., 2.3 km S jct. w/Hwy. 147, T12S, R4E, Sec. 28 (1, SIUC 19353).

* Site 3. Johnson Co., Cedar Creek at Hwy. 147, in Simpson, T12S, R4E, Sec. 22 (3, SIUC 19414).

Site 4. Pope Co., Hayes Creek at Hwy. 145, 4.8 km E Glendale, T12S, R5E, Sec. 23 (1, SIUC 19424).

Site 5. Pope Co., Sugar Creek at Hwy. 146, 1.6 km W Dixon Springs, T13S, R5E, Sec. 5 (1, SIUC 19373).

Site 6. Bay Creek at Hwy. 145, 3.2 km S Dixon Springs, T14S, R5E, Sec. 5 (2, SIUC 19393).

Cache River drainage

Site 7. Alexander Co., Sandy Creek at Diswood, T15S, R2W, Sec. 10 (32, SIUC 19298).

Site 8. Alexander/Pulaski cos., Mill Creek 2.4 km WNW Ullin, T14S, R1W, Sec. 22 (4, SIUC 19921).

Site 9. Pulaski Co., Mill Creek 3.2 km W Ullin, T14S, R1W, Sec. 28 (8, SIUC 19889).

* Site 10. Union Co., Big Creek 1.6 km E Dongola, T13S, R1E, Sec. 30 (1, SIUC 19952).

* Site 11. Johnson Co., Lick Creek 1.6 km NE Elvira, T12S, R2E, Sec. 6 (5, SIUC 19951).

Ohio River drainage

* Site 12. Alexander/Pulaski cos., Cache River just E jct. Hwy. 3 and Hwy. 127, T16S, R16E, Sec. 12 (1, SIUC 19974).

Figure 1. Distribution of *Cyprinella venusta* in Illinois. Dots represent localities with extant voucher material but not necessarily extant populations. Data are: year of collection(s) followed by the number of specimens taken. A, Big Muddy River. B, Clear Creek. C, Orchard Creek. D, Cache River. E, Ohio River.

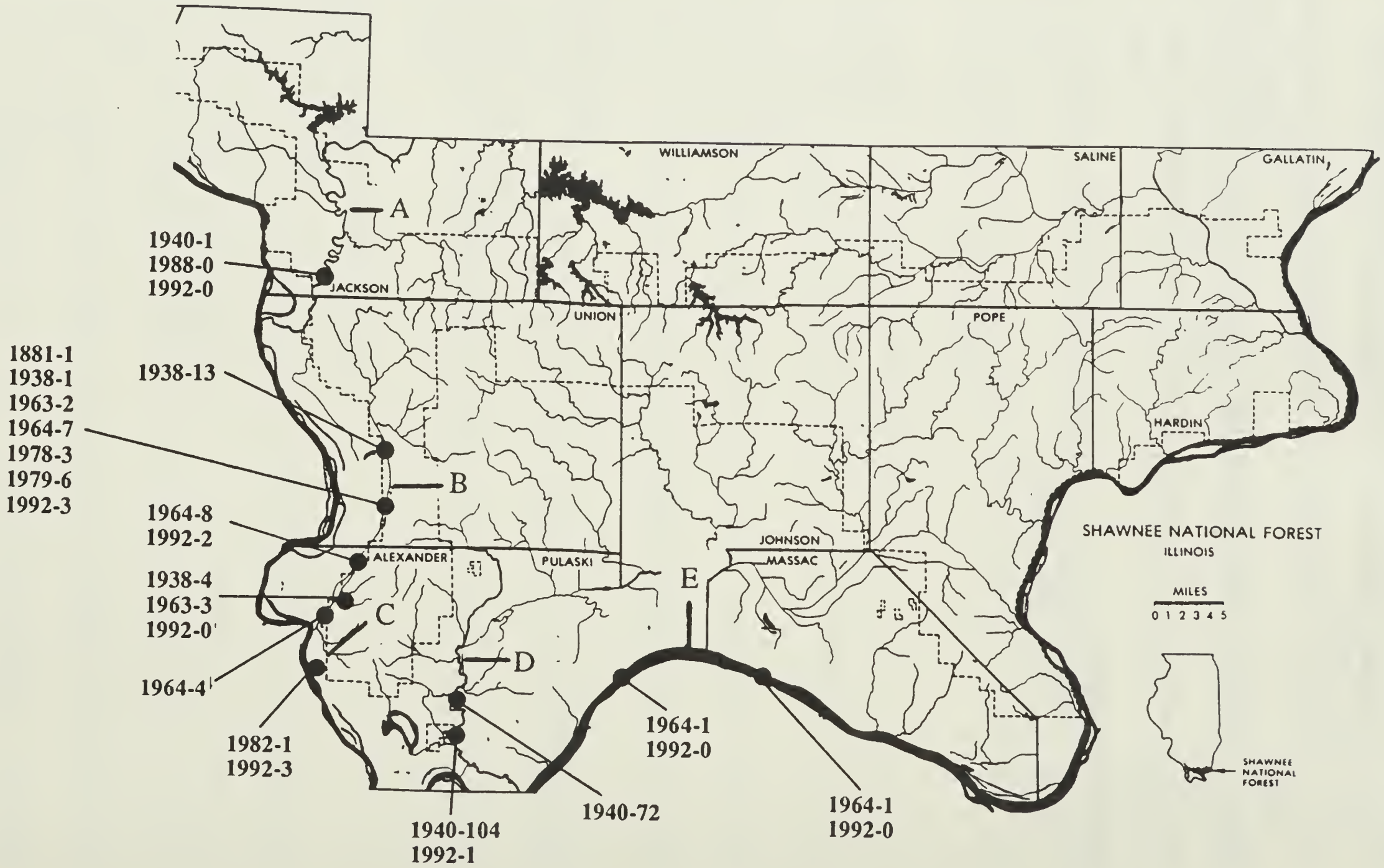


Figure 2. Distribution of *Fundulus dispar* in Illinois. Dots represent localities with extant voucher material but not necessarily extant populations. Data are: year of collection(s) followed by the number of specimens taken. A, Sugar-Rock River. B, Fox River Chain-of-Lakes. C, Wolf Lake. D, Kankakee River. E, Illinois River. F, Wabash River. G, LaRue-Pine Hills Ecological Area.

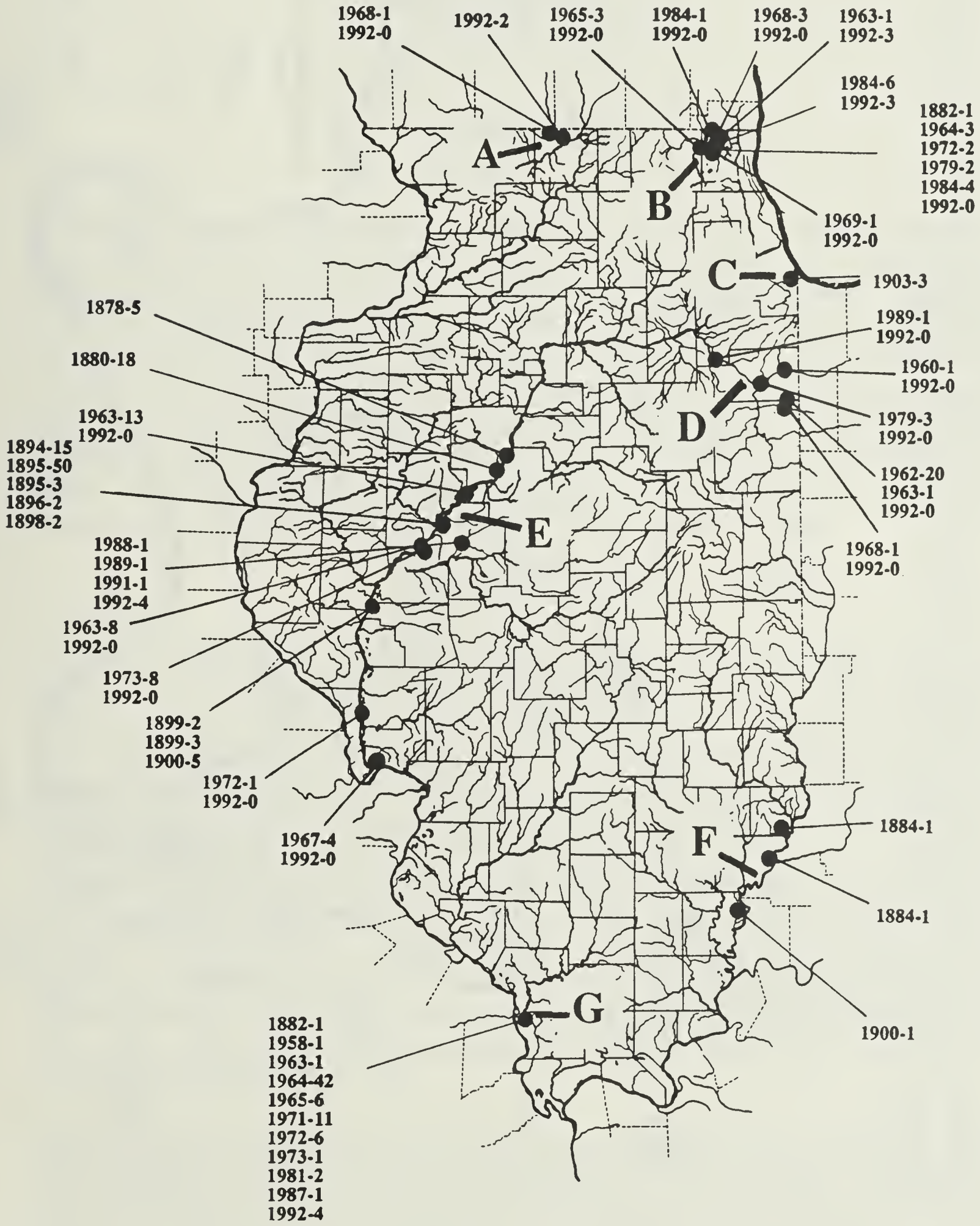
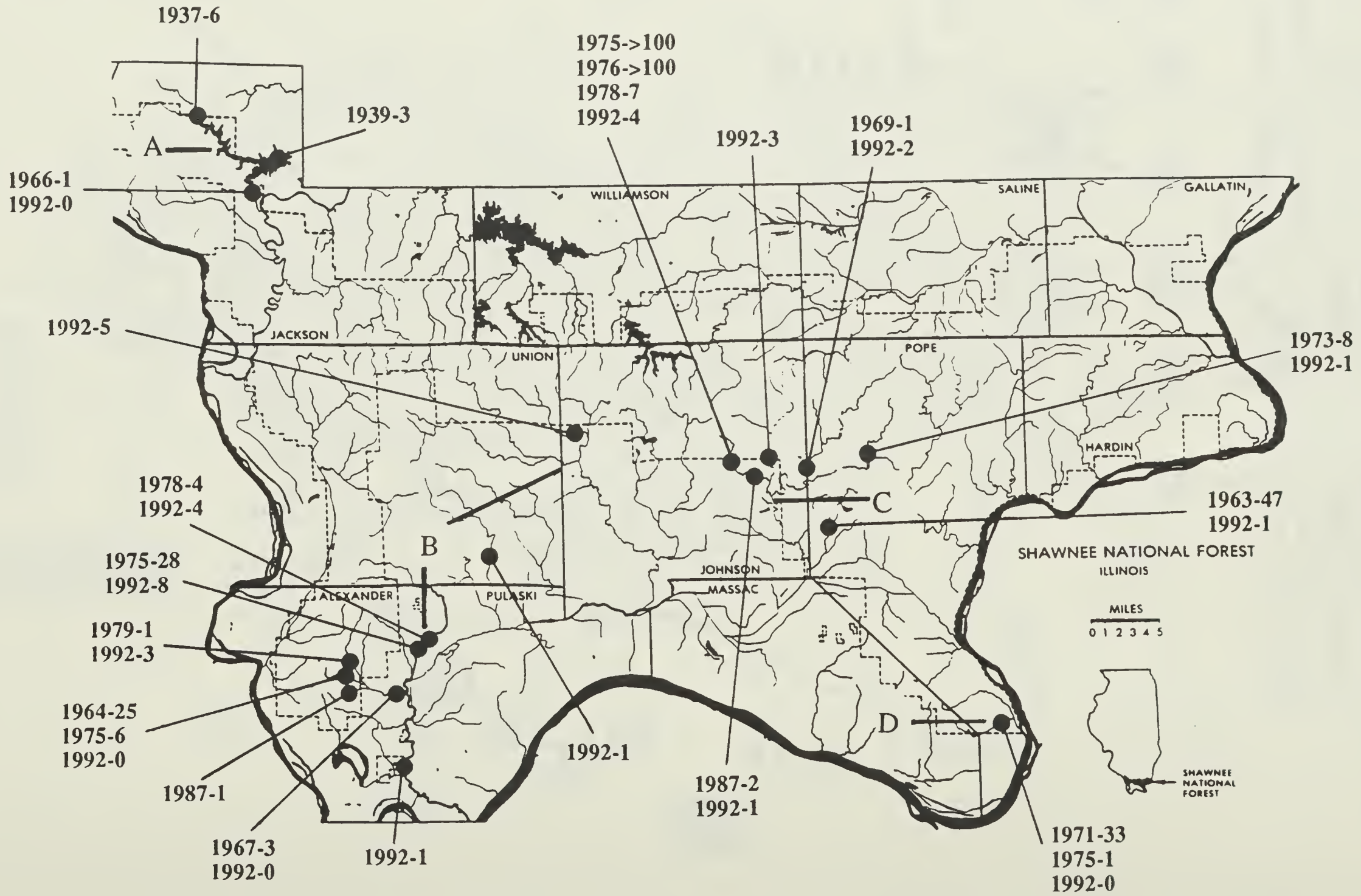


Figure 3. Distribution of *Etheostoma proeliare* in Illinois. Dots represent localities with extant voucher material but not necessarily extant populations. Data are: year of collection(s) followed by the number of specimens taken. A, Kincaid Creek. B, Cache River. C, Bay Creek. D, Alcorn Creek.



Transactions of the Illinois State Academy of Science
(1994), Volume 87, 1 and 2, pp. 83 - 97

Experimental Return of Wood Frogs to West-Central Illinois

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ABSTRACT

Habitat and climatic changes suggest a continued shrinking of the southern margin of the range of *Rana sylvatica* in many states of the USA. Reintroduction and habitat improvement were studied as methods to resist local and regional extirpation. Eggs from Indiana were translocated to a west-central Illinois county (McDonough) where this frog has been absent in historic times. Data over a 12 year period confirm the development of a breeding population, whose size and local distribution are increasing despite frequent drought conditions. These first seven known years of breeding in McDonough County will hopefully lead to a long surviving study colony, and observations of the methods and results should help others trying to preserve this frog locally. Some general reintroduction and habitat improvement methods are briefly discussed.

INTRODUCTION

Rana sylvatica has a large boreal range across Alaska and Canada, including open arctic tundra. But south of Canada it tends to be found in cooler mesic forests, and has the common name "wood frog". Its range is now quite restricted in 12 states of the USA, and less so in North Carolina and Tennessee. Ashton (1976) lists the species as peripheral, rare, threatened, or extirpated in seven of these states. The present distribution indicates that former populations almost certainly occurred in Iowa and Nebraska. Peripheral relict populations indicate this in Conant and Collins (1991), map 333. It appears incontestable that the range of this species was displaced southward by the glaciers and has since shifted northward (see Porter, 1972, p. 258). An 1892 relict Peoria population (Garman, 1892) confirms the earlier presence of wood frogs in west-central Illinois. The present range reduction presumably followed climatic changes and a reduction of Illinois forests described by King (1981). These frogs were certainly more widespread in Illinois during the cooler, moister postglacial period indicated by more spruce and fir pollen (Dyson, 1962, p. 208; King, 1981).

Translocation and habitat improvement studies reported here provide methods to retard local disappearance of this species, or to reestablish it where extirpated. McDonough County was chosen for the introduction site, because (1) 27 years of field work in the area confirm that *R. sylvatica* was not already present, and (2) the author's residence near the study area allowed more frequent monitoring of the population. Such closer proximity to

a study population aids in gaining new information about the species, and some is reported here.

MATERIALS AND METHODS

Donor Area

The *R. sylvatica* source was Brown County in south-central Indiana. Wood frogs occur nearer to McDonough County to the north, near Rock Island County, Illinois. However, the geographic differences indicated by proposed subspecies, such as relative leg length, may reflect latitudinal trends (in this case a version of Allen's rule), so it seemed better to deviate less from the natural pattern of genetic polymorphism by using more southern donor material (see map in H. Smith, 1978, p. 64). The northern subspecies assignment to the former Peoria locality is probably a guess, since P. Smith (1961) said he saw no specimens.

Eggs were usually taken from one 200 m^2 pond, but once came from a bay of a larger nearby lake. Only a small fraction of the eggs present were taken. Thirty-two advanced larvae were taken in 1989; 16 adults in 1988; and three adults from Parke County, Indiana, in 1985 (Table 3). Eggs were more practical to find and transport (in 3.8 liter, or one gallon jars) and were usually released one mass at a time near the edges of ponds. Too little air space (water above the jar shoulders) or eggs occupying more than about 2/3 of the water volume can result in some mortality, so this was avoided. Eggs were kept cold (about 5-10^{o} C), and released as soon as possible (in about 6-18 hr.).

Translocation Area

The introduction area in McDonough County is about 8 km ENE of Macomb. Fig. 1 shows the topographic relief is greater than usual locally. The bluff slopes have allowed a better survival of earlier lumbered or pastured forest. Much of the forest is redeveloping oak-hickory protected for over 20 years. Locations of most of the relevant ponds or clusters of ponds are shown by circled numbers in Fig. 1. Individual ponds are referred to in the text by adding letters (1A, 1 1/2A, etc.). The pond numbers were assigned partly in chronological order of wood frog activity. As Table 1 mostly shows, the first releases were made at the pond 1 group in 1982; wood frogs then bred in the 2 group in 1987; eggs were released into pond group 3 in 1987; one frog called from pond 4 in 1988; larval transfers to pond 5 were attempted later in 1988; and wood frogs oviposited in pond group 6 in 1989. Pond groups 1 1/2 and 2 1/2 were enlarged and used for wood frog transfers still later (1991 and 1992) but these additional ponds were assigned numbers based on their position relative to pond groups 1 and 2. Pond 4 is not included in Tables 1-3 because wood frog eggs were never found or placed in pond 4.

Most ponds are surrounded by forest, but a more savannah-like environment exists near some on the mitten shaped "plateau" of upland in the lower right corner of Fig. 1 by area 2, at pond 4, and by the number 1 series of ponds. However, the steep NE facing bluff by the easternmost 1 pond (pond 1A) is forested, and cooler and more mesic conditions are indicated by the presence of basswood trees (*Tilia americana*) and wild ginger plants (*Asarum canadense* var. *reflexum*). All numbered ponds (Fig. 1 and Table 1) were hand dug by the author between 1984 and the present, except for the 1 oxbow series and a cluster at 6 which were dug about 100 years earlier.

Habitat Improvements

The most important habitat improvement favoring *R. sylvatica* was the creation (digging) of many breeding ponds in forested areas. Algae and other pond organisms (some named below) were added to hasten the development of adequate pond habitat. Some trees were removed or girdled to admit sunlight for more algal growth. One to three six-channel chimney flue tiles of 91 1/2 x 32 x 22 cm were sometimes placed on pond bottoms for added refuge from predators and from dessication as the pond dried. Often one to three dead branches (about 2-3 m long) were placed in the centers of ponds in spring to provide floating oviposition sites which move up and down with changing water levels. These were utilized by the frogs.

Adjacent disturbed oak-hickory forest habitat was improved by adding leaf duff, logs, tree plantings (mostly hard maples), and underground rock-pile retreats. These changes do favor *R. sylvatica*. Mulching conserves soil moisture and reduces soil temperature fluctuations. Shelford (1937) showed that a thicker forest floor leaf layer and more mature hard maple forest favored *R. sylvatica* in northern Illinois and Indiana. *R. sylvatica* and other amphibians were observed using the rock piles for shelter from dryness and temperature extremes.

Figures 2-4 show pond 2C at an earlier digging stage and in its final form in 1991, with *R. sylvatica* eggs. The basin is about 12 by 15 m, with deepest spots to about 2 m. All other dug ponds were smaller (to a minimum size of about 2 x 1 x 1 m) and the amount of water varied with the weather.

Monitoring Methods

Mark-recapture methods and traps or drift fences were not used to monitor the frog populations because they can increase mortality. An encircling fence around a pond of metamorphosing tadpoles may sound effective, but could result in major slaughter by the frequently patrolling raccoons (*Procyon lotor*) in the area.

The methods that evolved included conservative estimates of the number of eggs in released or oviposited egg masses. The egg number per mass varies and can be much less than some estimates given in the literature. It was impossible to accurately count eggs in a large three-dimensional egg mass without damaging them. When larvae of wood frogs alone were transferred between ponds, these were counted. The relative numbers of larvae were followed by estimates or minimum counts of animals seen at the surface on clear sunny days. Less than two weeks from the start of metamorphosis, all or nearly all larvae were usually dipnetted from the ponds and counted as they were placed in pails and soon returned to their ponds. In the two largest ponds (1A and to a lesser extent 2C) netting was not effective in catching most of the tadpoles, and more general estimates were made based partly on data for other populations, partly reviewed in Duellman and Trueb (1986). With the exception of pond 1A, however, tadpoles were monitored throughout each season and estimates modified by events and conditions at each pond. A permanent record was recopied from field notes each year. This semi-quantitative data is accurate enough to show trends and make comparisons.

RESULTS

General History of Releases and Breeding

Estimated numbers or counts of ovipositions, releases, transfers, and metamorphoses are given for individual ponds in Table 1. Table 2 shows summed values for the three main areas: I--the main river valley (pond series 1) and adjacent lower eastern tributary valley; II--the upper eastern tributary valley and slopes (pond series 1 1/2, 2, and 2 1/2, and 4); and III--the western tributary area and westward (pond 5 and pond groups 3 and 6). Finally the grand totals per year are summarized in Table 3.

As shown in Table 1, no eggs developed to metamorphosis the first year (1982). This was because they were placed in small streamlet pools in forested area X, and all these bodies of water dried up before metamorphosis, and were not used subsequently. No translocations were made in 1983, 1986, 1990, or after 1991. But in 1984 and five later years (Table 1) most releases were made at the easternmost main valley pond 1A. This was the best group 1 pond in that it lasted the longest most seasons and had the best quality adjacent forest (at X). Eggs were only found once in any other main valley pond (adjacent 1B), and that pond dried before they could metamorphose. There are actually about five oxbow ponds between the two southern tributaries in Fig. 1, and these were all examined in most years.

There are habitat trends at pond 1A, whose quality has gradually diminished because it has been silting in. Twenty years ago it supported a colony of beavers. Later it supported muskrats and turtles. Now this roughly 15 by 105 m curved pond rarely gets much more than 1 m deep and is more subject to outside influences. The effects of the "50-year" 1988 drought were not strongly felt until 1989, when 1A was essentially dry except for a 3 x 2 x 1 m pit that had been dug in the bottom (in 1988). Thirty-two nearly metamorphosed Indiana *R. sylvatica* larvae were placed in this pit and hopped out soon afterwards. The next year pond 1A was refilling, and most of the wood frog eggs were suffocated when the water level rose about 1/3 m above the oviposition level and the eggs fell into 1 m deep water. An extra translocation was made in 1991 to aid recovery from the bad years. The number of successfuly metamorphosing animals, both total and at 1A, appeared to be the largest ever but was exceeded in 1993.

However, in 1992 there were unusual cold snaps. Although breeding started earlier than most years (first calls on March 3rd, first eggs on the 5th, and eggs confirmed at 1A by the 8th), the air temperature dropped from above 10° C to below -10 1/2° C on March 11th. It must have been still colder during the night, and the shallow weed bed where the eggs were laid was exposed to a wind chill from NW winds. The eggs looked dead later, and no eggs hatched when one mass was transferred and observed in a smaller pond (3A). Dan Wise of the Western Illinois University Geography Department confirmed that 1992 was the coldest summer in local weather recording history (since 1950). He and other meteorologists attribute this in part to dust thrown up by volcanoes in recent years (pers. comm.)

Tables 1 and 2 also show trends for areas II and III. The first confirmed *R. sylvatica* breeding in McDonough County since at least 100 years (and probably many more) took place in II when some (more than 3) apparently two and three-year-old wood frogs arrived

in 1987. They called in nine ponds in the southernmost part of Group 2, and one egg mass was oviposited in 2A. Both area II and III populations were satellites of 1A at first but are increasing, with oviposition at an increasing number of ponds (Table 1). In addition, eggs were first laid at 2 1/2B and 3B in 1993.

Table 3 shows the establishment of a breeding colony from releases in 1984-85 and 1987-88, and an apparent recovery from the effects subsequent to the 1988 drought. Oviposition levels gradually increased again, to the highest level ever. The second greatest number of successful metamorphoses occurred in 1992, even though there was only one more supplementary egg translocation in 1991, plus 32 larvae in 1989. Still greater estimates were made for 1993 after this manuscript was submitted; about 16,000 eggs laid and over 2,500 of these metamorphosed. The percent metamorphosis in Tables 2 and 3 is the number estimated to metamorphose, divided by the sum of the estimated numbers of releases and ovipositions.

Estimates of the metamorphosed population are difficult to make because the animals are so secretive. Twenty-two egg masses were found in 1992, indicating at least this many adult females. More than 28 calling males were heard in 1992, some at ponds where no oviposition occurred. If you assume that sexually immature frogs make up about 50% of the population as in *R. pretiosa* (Turner, 1960), there would be at least 50 immatures. This total of 100 is too small, since almost 2,000 frogs were estimated to have metamorphosed in 1991 (Table 3). An estimated 943 more metamorphosed in 1992, though only one of these was seen later, in early August of 1992. From the above, the total metamorphosed population of wood frogs in McDonough County probably reached about 1,000 or more in 1992. Of course there was winter mortality, but 1993 breeding data just obtained confirms that the population is established and growing. At least 43 egg masses were found; about the same number as in 1992 for area I (but this year none died from freezing), more in area II, and much more (19 instead of 1) in area III.

Egg Mortality Factors

The main egg mortality factor observed during this study was water level change. Egg masses dessicated if the water level dropped, or suffocated when the water level rose. This could be compensated for to some degree if the egg mass was deposited either on a flexible weed stem that hung down into the water or on floating sticks which were usually present. Sometimes relocated egg masses were moved in time to reduce losses. Egg masses could also suffocate if they slid down the slanting bottom to deeper water or broke loose from an attachment (perhaps after wave action, or in two cases from being examined too often). Some eggs hatched anyway after getting into deeper water. In the worst case two egg masses fell into water about 1 m deep for two days. They were fished out with a net, and roughly one half hatched after a delayed development.

Cold shock can kill *R. sylvatica* eggs. However, egg masses were found with the upper part encased in ice yet there was little subsequent damage after warmer temperatures returned. The loss of about 6,000 eggs to cold at 1A in 1992 was unusual.

Predation of wood frog eggs by either vertebrates or invertebrates was not observed.

Larval Mortality Factors

Premature pond drying and predators were the two major causes of larval mortality. Food shortage also contributed. The wood frog does not need permanent ponds to breed in, but requires only vernal pools that last until about June 15th in this area. However, newly dug ponds were small (a "D" in Table 1 indicates the year digging started) and were more subject to drying before silt sealed the bottom of the clay basins. In some cases pond drying was circumvented by adding water or by transferring larvae to other ponds. Newer ponds 2 1/2A and B (west of "(2)" in Fig. 1) are droughtproof, because they can be refilled through garden hoses from a house. New ponds are oligotrophic, and insufficient plant food causes stunting and presumably increased mortality. When stunting became obvious, the populations were sometimes thinned by transfer to other ponds, but more often algae were added (frequently *Spirogyra*). As the ponds become older and sometimes larger, some eventually can last until the time of metamorphosis and have the nutritive resources to support more than one egg clutch. Asterisks in Table 1 mark the years in which some of the ponds reached this partial independence from food and water additions. Older ponds 1A and group 6 did not get any aid, except for some pond deepening and shade reduction. Some of the ponds will not be used for future larval transfers, and to some degree the *R. sylvatica* appear to pick the better available ponds for oviposition.

Metamorphosing froglets probably leave the ponds at night during a rain, although some were seen leaving drying ponds in daytime without rain. In the 1988 major drought, the forest duff became dry, and some late metamorphosing froglets stayed by the moisture of a small pond basin (2A), whose drying was delayed until July 8 by adding buckets of water. The froglets took refuge from dessication within sunbaked cracks in the clay bank. After the first good rain (on July 17) they all disappeared, presumably dispersing into the forest floor duff.

Predators were the most dramatic larval mortality factor, and there were many predators of varying importance over the years. Their effects were less in the small ponds deeper in the woods and worse in more open valley areas, most notably at 2C, 2B, and probably 1A. Raccoons were serious predators only partly kept in check by coyotes, dogs, and hunters. A few breeding *R. sylvatica* were found partly eaten, and raccoon tracks increased as the ponds dried. A few mink (*Mustela vison*) were present but no predation of wood frogs was confirmed. Birds were not major predators either as occasional visits by great blue herons (*Ardea herodias*), green-backed herons (*Butorides striatus*), or kingfishers (*Megaceryle alcyon*) to ponds 1A and 2C appeared to have little effect on *R. sylvatica* larvae numbers. Among reptiles, immature northern water snakes (*Nerodia sipedon*) contributed to noticeable losses at 2C (and nearby 2B, 2D, and 2E) in some years. Turtles (mostly *Chrysemys picta*) probably caused some losses in 1A. Bullfrogs (*Rana catesbeiana*) probably caused some losses at 1A, 2C and 2B. Smallmouth salamander larvae (*Ambystoma texanum*) were numerous in most ponds but were not large enough to prey on wood frog tadpoles. Some tiger salamander (*Ambystoma tigrinum*) larvae introduced from local sources largely eliminated the *R. sylvatica* tadpoles in 2C and adjacent 2B in 1988. *Ambystoma tigrinum* have not reproduced or caused predation since. Fish were usually kept out of the ponds, but in 1990 tiny green sunfish (*Lepomis cyanellus*) were accidentally introduced into 2B, 2C, and 2D with aquatic vegetation, along with four small goldfish (*Carassius auratus*) in 2B. The fish grew larger and decimated the tadpoles in 1991 before being recognized. Subsequently, fish were almost

completely removed by draining and seining the ponds, apparently caused no problem in 1992, and will be monitored in future years.

The usual invertebrate predators of tadpoles are also present. Water spiders, *Notonecta sp.*, and some of the larger water beetles presumably took some smaller tadpoles. The more dangerous predators of larger tadpoles are dragonfly and water tiger (*Dytiscidae*) larvae. The latter increased in some of the smaller ponds in 1991. A leech was once observed feeding on an apparently injured wood frog tadpole, and another leech did so when accidentally confined with four tadpoles in an aquarium.

Competition

There are six common and three uncommon species of frogs in the study area, eight of which have ranges that broadly overlap that of *R. sylvatica* but also occupy large areas outside its range. These eight species have prospered in both areas, and to my knowledge no published reports show a marked negative effect by *R. sylvatica* on these widespread forms. At least seven have used the new breeding ponds. If tadpoles of other species share the same pond with *R. sylvatica* tadpoles, there is some possiblity of competition for resources, particularly for the numerous *Pseudacris triseriata* and *Bufo americanus* tadpoles. But both species are smaller and feed differently. Four other species breed later in the year, including bullfrogs which find all the ponds but 1A and 2C too small to breed in. If some of these other resident frog populations decrease in the future, it will probably be from continued environmental deterioration and not from the presence of *R. sylvatica*.

The one local frog species whose range does not overlap the wood frog range widely is *Rana blairi*. This medium sized *Rana* is dominant among similar sized members of the same genus in much of Transeau's Prairie Peninsula and the plains for which the frog is named. It is certainly the dominant medium sized *Rana* in McDonough County and can be found in or near most ponds, including *R. sylvatica* breeding ponds. However, *R. blairi* generally does not feed from or shelter in the forest floor like the wood frog. And *R. blairi* mostly breeds in ponds surrounded by open land and not utilized for *R. sylvatica* breeding. However, some intermediate type ponds can be used by both species. Both have bred in 1A, the *R. blairi* choruses calling a little later (but overlapping *R. sylvatica*) and mainly from the opposite end of the elongated pond. The *R. blairi* eggs were in deeper water out of the wind and partly survived the 1992 cold shock. *Rana blairi* has sometimes called from 2B, 2C and 2D in recent years, and laid a few eggs in 2C and 2B. Tadpoles of the two species are more similar in size and feeding habits, eating algae near the surface away from the shallows. Their food use appears to overlap more. However, most *Rana* habitat in McDonough County is favorable for the fairly abundant *R. blairi* but not for *R. sylvatica*.

In 1993 ecological and temporal isolating mechanisms were clearly evident. The wood frogs mainly bred on March 30 or 31st (41 of 43 egg masses). They abandoned ponds 1A and 2C in more open areas, and utilized other ponds in more wooded areas nearby. Calls from *Rana blairi* were not heard until the next rain, on April 7th. Three egg masses from *Rana blairi* were found in 1A on April 9th and no *R. sylvatica* eggs (the pond was waded and carefully examined on April 3rd and 9th). One *R. blairi* egg mass may have been oviposited a few days earlier in a pond not used by *R. sylvatica*. Only pond 2B contained

eggs from both species, and there was no time overlap. Long after their breeding season was over (by July) *Rana blairi* still have not ovoposited in any other pond with *R. sylvatica* eggs.

DISCUSSION

Most vertebrate and invertebrate animal introductions have not been monitored or studied carefully, other than some birds and mammals in more recent years. *Rana sylvatica* can be introduced (or reintroduced) into areas of locally mesic wooded habitat and even disturbed woodland in drier areas like west-central Illinois if certain habitat improvements are made. The scarcity of both forests and suitable forest ponds in today's cornfield-modified Illinois Prairie Peninsula makes it obvious why *Rana sylvatica* is mostly absent. However, there are still bits of habitat that could support the wood frog if it could reach them.

One other successful translocation of *R. sylvatica* eggs has been made by Sexton and Philips (1986) in St. Louis County, Missouri, presumably using local donor populations. If one is conveniently near a donor pond, a higher survival rate can be obtained by dipping up recently hatched larvae before they have dispersed from the egg mass.

Survival rates vary per pond and year. One of Sexton and Philips' introductions succeeded and one did not. In the present study, the largest breeding choruses in areas I, II and III could shift from a local pond used in a previous year and form at a nearby pond that was currently larger or more suitable. This tended to increase the number of successful metamorphoses. Estimated survival rates from eggs to metamorphosis (Table 1) varied from 0-87% in different ponds for different years. These values would be still lower if egg number estimates are too conservative. Many survival rates may seem excessively low in these oligotrophic and short lasting new ponds. However, in Alaska, Herreid and Kinney (1966) estimated the average egg fertilization success in nature as 86.7% and that only 3.7% of these zygotes survived to metamorphosis. Duellman and Trueb (1986) show 4.8% and 5.2% for two other *Rana* (Table 11-3). In my study tadpoles in smaller ponds farther from streams appeared to suffer less predation but were more vulnerable to food (algae) shortage or premature pond drying.

Rana sylvatica can be translocated successfully for conservation or study purposes, but translocations should not be attempted without a reason. One should keep and publish records, and should not (1) overcollect donor populations, (2) place donors far outside the general region or biome that they come from, nor (3) greatly alter the pattern of genetic polymorphism in a continuous population.

The *R. sylvatica* population formed here has other usefulness besides contributing information about survival factors. Like the former Peoria population, this is a disjunct or "outpost" colony, near the range border, in a generally unfavorable macroclimate. If there are long term unfavorable climate trends, these *R. sylvatica* could serve as an indicator population to show how much these conditions can be offset by a redeveloping favorable habitat and microclimate.

The future of this population involves survival and possible spread. Protection of forest and breeding ponds are necessary for survival. As Fig. 1 shows, the area is encircled by a road so further possible local spread can easily be monitored from a car by listening for calling in March. The habitat gets worse in all directions, so successful dispersal is not too likely. It is possible but not likely that tadpoles could be washed downriver in a flood and survive to reach and populate suitable habitat.

ACKNOWLEDGEMENTS

Partial support for this work was provided by 1986 and 1987 grants from the Illinois Department of Conservation utilizing tax check-off funds. I would also like to thank the Indiana Department of Conservation for collecting permits, and my family and Harry and Trevor Toland for their assistance. I also thank Ed Franks and anonymous reviewers of earlier drafts for assistance with manuscript preparation.

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Table 1. *Rana sylvatica* use of numbered study area ponds, 1982-1992.

Pond	Eggs	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
1A	RL	1000*	0	1000	3000	0	2350	7800	32	0	6700	0
	OV						?	5600		3000	2800	6000
	MT	0		100	300		200	500	30	30	900	0
1B	OV							1200				
	MT							0				
1 1/2A	RL						D				154	
	MT										2	
1 1/2B	RL					D					500	
	OV										0	1000
	MT										300	300
1 1/2C	RL						D				446	*
	OV											400
	MT										40	200
1 1/2D	RL						D				300	
	MT										0	
2A	RL			D							800	
	TR								200	50		200
	OV						200	400				
	MT						100	150	60	0	200	7
2B	RL		D								1000*	
	TR									100		
	OV							200			400	800
	MT							20		5	5	110
2C	RL					D					900*	
	OV							200	400	350	800	1500
	MT							30	60	20	0	50
2D	RL					D					300	
	TR											150
	OV										900	
	MT										0	1
2E	RL		D								500	
	TR											100
	OV										150	
	MT										15	5
2 1/2A	TR										D	100
	MT											13
2 1/2B	TR					D					150	150
	MT										50	15
6	OV								200*			
	MT								20			
3A	RL					D	250	50			400	
	TR							57	12	40		330
	OV										200	
	MT						3	40	10	0	400	2
3B	RL						D				100	*
	TR								23	40		75
	MT								20	5	50	20
3C	RL						D				100	
	TR									20		75
	MT									3	15	20
5	TR					D		?				*
	OV											300
	MT							10				200

Abbreviations: RL = estimated number of Indiana eggs released; TR = estimated number of eggs or larvae transferred to the pond from another local pond; OV = estimated number of eggs oviposited; MT = estimated number of frogs metamorphosing from the pond; D = the year digging started for the pond; * = approximate year the pond no longer required additions of water or food.

Table 2. Summed *Rana sylvatica* use for three area subdivisions, 1982-1992.

	Area I (pond 1 series)					Area II (pond series 1 1/2, 2, 2 1/2)					Area III (pond series 3, 5, 6)				
1982	1000	RL	0	MT	0%										
1983															
1984	1000	RL	100	MT	10%										
1985	3000	RL	300	MT	10%										
1986															
1987	2350	RL	200	MT	9%						250	RL	3	MT	1%
	?	OV				200	OV	100	MT	50%					
1988	7800	RL				800	OV	200	MT	27%	50	RL			
	6800	OV	500	MT	3%	(-57)					57	TR	50	MT	48%
1989	32	RL	30	MT	"94%"	400	OV	120	MT	33%	200	OV			
(larvae)						(-35)					35	TR	50	MT	21%
1990	3000	OV	30	MT	1%	350	OV	25	MT	10%					
						(-100)					100	TR	8	MT	8%
1991	6700	RL				4900	RL				600	RL			
	2800	OV	900	MT	9%	2250	OV				200	OV	465	MT	58%
	(-150)					150	TR	612	MT	8%					
1992	6000	OV	0	MT	0%	3700	OV	701	MT	20%	300	OV			
	(-300)					(-180)					480	TR	242	MT	31%
Sum	40482		2060	MT	5%	12378		1758	MT	14%	2272		818	MT	36%
Average of annual %				15%					25%					28%	

Abbreviations: Same as in Table 1, but here TR is only from outside the subdivision.

Table 3. Total *Rana sylvatica* study area use, 1982-1992.

	RL	OV	MT	%	Average Subdivision % (from Table 2)	Ind. adult release (1A)
1982	1000	0	0	0%	0%	
1983	0	0	0			
1984	1000	0	100	10%	10%	
1985	3000	0	300	10%	10%	3
1986	0	0?	0?			
1987	2600	200 (more in 1A?)	303	11%	20%	
1988	7850	7600	750	5%	26%	16
1989	32 (larvae)	600	200	32%	49%	
				33% eggs only	27% eggs only	
1990	0	3350	63	2%	6%	
1991	12200	5250	1977	11%	25%	
1992	0	10000	943	9%	17%	
Sum	27332	27000	4636	9%		19
Average of 9 annual %				10%	16% (eggs only)	

Figure 1. McDonough County, Illinois, wood frog translocation area (USGS Topographic Maps). The circled numbers indicate ponds or pond groups. The "X" marks the location of the most favorable local habitat, mature white oak forest.

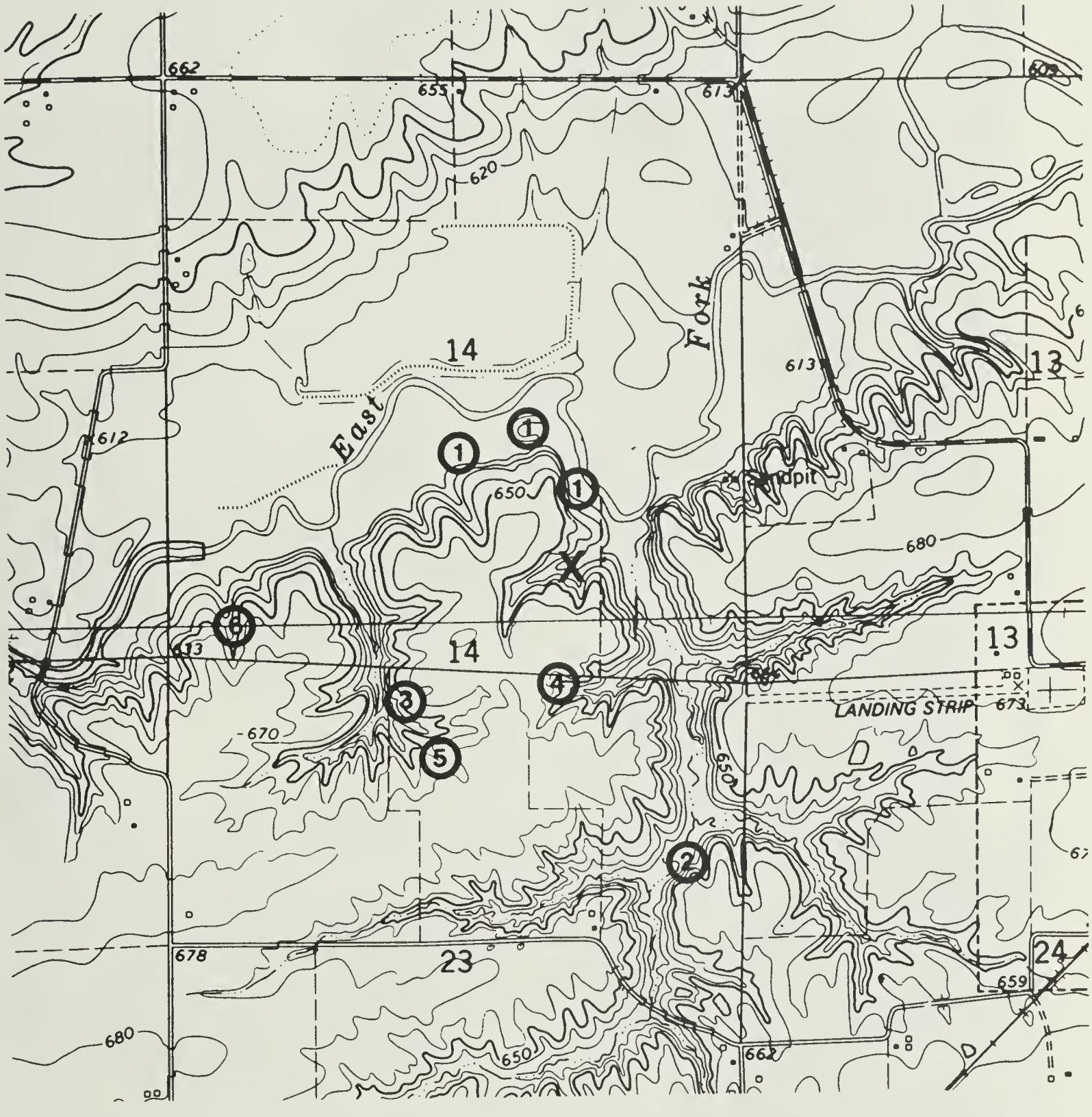

Figure 2. Pond 2C during its excavation (1987). The scale is shown by the shovel.

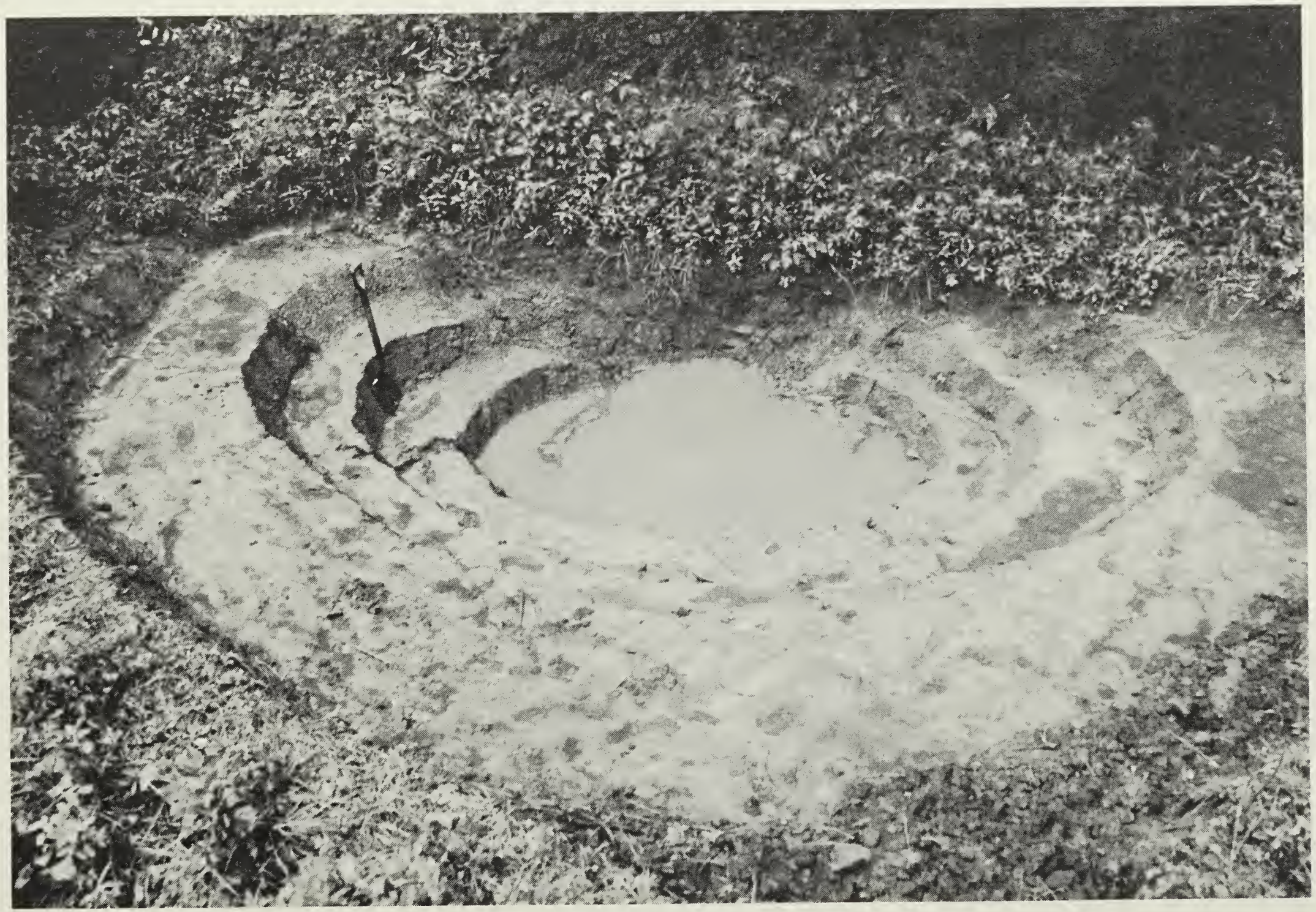

Figure 3. Pond 2C in March 1991. The scale is shown by the wheelbarrow.

Figure 4. Wood frog eggs oviposited in Pond 2C, March 1991.

Transactions of the Illinois State Academy of Science
(1994), Volume 87, 1 and 2, pp. 99 - 109

Checklist of the Freshwater Fishes of the Little Wabash River Drainage in Effingham County, Illinois with Comments on Possible Changes in Faunal Composition

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ABSTRACT

A checklist of 55 species of fishes is presented based on museum records and field collections made from July through September, 1991, at 27 localities in the Little Wabash River drainage in Effingham County, Illinois. Thirteen species are reported from Effingham County for the first time. *Morone mississippiensis* is recorded in the Little Wabash River drainage for the first time. Seven species previously reported from the county were not recollected in 1991. Records reported here for six species, including *Lythrurus fumeus, Lepomis microlophus, Minytrema melanops, Aphredoderus sayanus, Etheostoma asprigene*, and *Aplodinotus grunniens*, are the northern most records for the species in the Little Wabash River drainage. Except for *Etheostoma asprigene*, which was not recollected during the current study, these species may have expanded their ranges northward. Two others, *Gambusia affinis* and *Morone mississippiensis*, may also have done so. Of the seven species not collected in 1991, six respond negatively to increased siltation, and at least four of the seven species thought to have expanded their ranges prefer mud or silt bottoms.

INTRODUCTION

The only previously published information on the fishes of Effingham County can be found in Smith (1979), who found that the headwaters of the Little Wabash River contained a diverse fauna. He also noted the possible impact of siltation and oil field pollution on the river and its fishes. My study reports on the fishes caught at 27 collecting stations (Figure 1) in the Little Wabash River drainage from July through September of 1991.

SETTING

Effingham County is located in south-central Illinois. With the exception of Wolf Creek of the Kaskaskia River drainage, streams in the county are part of the Little Wabash River drainage. The county lies south of the Shelbyville Moraine and south of the Prairie

Peninsula. Vegetation is mixed and includes southern division woodlands and prairie (Smith, 1961). Streams in the northern half of the county have sand-gravel-stone bottoms, and those in the southern half more commonly have mud or silt bottoms (Smith, 1979).

MATERIALS AND METHODS

Fishes were caught using a 4-m seine with a 4.5-mm mesh or with hook and line using both small and large hooks. Both methods were used at each locality sampled. Fishes were identified using Smith (1979) and Page and Burr (1991). Difficult identifications were confirmed by comparison to specimens in the collections of the Illinois Natural History Survey. Voucher specimens were deposited in the Illinois Natural History Survey and at Southern Illinois University at Carbondale. Records from the Illinois Natural History Survey (INHS), Southern Illinois University at Carbondale (SIUC), and University of Michigan Museum of Zoology (UMMZ) were used to complete the checklist.

Of the 27 localities sampled, 9 were from the Little Wabash proper, 17 were from tributaries, and 1 was from an impoundment. At each locality, at least two pools and three riffles were seined. After seining, hook and line fishing was employed in each of the pools. Except for *Aplodinotus grunniens* and *Morone mississippiensis*, species caught by hook and line were also represented in seine samples.

Localities were chosen on the basis of two criteria. First, I sampled all localities that had previously been sampled by the crews from the Illinois Natural History Survey or Southern Illinois University at Carbondale. Second, localities not previously sampled were chosen if permission to seine could be obtained and if the locality could be easily reached by automobile. In those instances where records existed for fishes not yet collected by me in 1991, multiple visits were made to the localities in an attempt to recollect those species. Locality 4, the most intensively sampled station, was visited 6 times over the course of the study. Localities 7, 10, 11, and 25 were visited three times and localities 5, 6, 11, 16, and 17 were each visited twice. The remaining localities were visited once. Appendix 1 describes the 27 localities sampled in 1991.

CHECKLIST

The checklist is based on specimens in the collections of INHS, SIUC, and UMMZ along with species collected during the current study. All species reported including new records (marked with an *), are supported by specimens in institutional collections. Nomenclature follows that of Page and Burr (1991). Order of presentation follows that of Smith (1979). Species marked with an epsilon (ε) are thought to be extirpated from the county.

Family Clupeidae (Shads)	
Dorosoma cepedianum (Lesueur, 1818)	Gizzard Shad
Family Cyprinidae (Minnows)	
Cyprinus carpio Linné, 1758	Common Carp
Notemigonus crysoleucas (Mitchill, 1814)	Golden Shiner

Semotilus atromaculatus (Mitchill, 1818)	Creek Chub
Nocomis biguttatus (Kirtland, 1841)	Hornyhead Chub ε
Campostoma anomalum (Rafinesque, 1820)	Central Stoneroller
Phenacobius mirabilis (Girard, 1856)	Suckermouth Minnow
Luxilus chrysocephalus Rafinesque, 1820	Striped Shiner
Lythrurus fumeus Evermann, 1892	Ribbon Shiner *
L. umbratilis (Girard, 1856)	Redfin Shiner
Cyprinella spiloptera (Cope, 1866)	Spotfin Shiner
C. whipplei Girard, 1856	Steelcolor Shiner
Pimephales notatus (Rafinesque, 1820)	Bluntnose Minnow
P. vigilax (Baird and Girard, 1853)	Bullhead Minnow *
Notropis boops Gilbert, 1884	Bigeye Shiner ε
N. ludibundus (Girard, 1856)	Sand Shiner
Hybopsis amblops (Rafinesque, 1820)	Bigeye Chub ε
Ericymba buccata Cope, 1865	Silverjaw Minnow
Family Catostomidae (Suckers)	
Carpiodes cyprinus (Lesueur, 1817)	Quillback
Catostomus commersoni (Lacépède, 1803)	White Sucker
Minytrema melanops (Rafinesque, 1820)	Spotted Sucker *
Erimyzon oblongus (Mitchill, 1815)	Creek Chubsucker
Hypentelium nigricans (Lesueur, 1817)	Northern Hog Sucker
Moxostoma erythrurum (Rafinesque, 1818)	Golden Redhorse
M. macrolepidotum (Lesueur, 1817)	Shorthead Redhorse
Family Ictaluridae (Bullhead Catfishes)	
Ictalurus punctatus (Rafinesque, 1818)	Channel Catfish *
Ameiurus melas (Rafinesque, 1820)	Black Bullhead
A. natalis (Lesueur, 1819)	Yellow Bullhead *
Noturus gyrinus (Mitchill, 1817)	Tadpole Madtom
N. miurus Jordan, 1877	Brindled Madtom
Family Aphredoderidae (Pirate Perches)	
Aphredoderus sayanus (Gilliams, 1824)	Pirate Perch *
Family Fundulidae (Topminnows and Killifishes)	
Fundulus notatus (Rafinesque, 1820)	Blackstripe Topminnow
Family Poeciliidae (Livebearers)	
Gambusia affinis (Baird and Girard, 1853)	Mosquitofish *
Family Moronidae (Temperate Basses)	
Morone mississippiensis Eigenmann, 1887	Yellow Bass *
Family Centrarchidae (Sunfishes and Basses)	
Pomoxis annularis Rafinesque, 1818	White Crappie *
Micropterus punctulatus (Rafinesque, 1819)	Spotted Bass
M. salmoides (Lacépède, 1802)	Largemouth Bass
Lepomis cyanellus Rafinesque, 1819	Green Sunfish
L. gulosus (Cuvier and Valenciennes, 1829)	Warmouth *
L. humilis (Girard, 1857)	Orangespotted Sunfish
L. macrochirus Rafinesque, 1819	Bluegill
L. megalotis (Rafinesque, 1820)	Longear Sunfish
L. microlophus (Günther, 1859)	Redear Sunfish *

Family Percidae (Darters)	
Percina caprodes (Rafinesque, 1818)	Logperch
P. maculata (Girard, 1859)	Blackside Darter
P. phoxocephala (Nelson, 1876)	Slenderhead Darter
P. sciera (Swain, 1883)	Dusky Darter
Etheostoma asprigene (Jordan, 1878)	Mud Darter * ε
E. blennioides Rafinesque, 1819	Greenside Darter
E. chlorosomum (Hay, 1881)	Bluntnose Darter ε
E. gracile (Girard, 1859)	Slough Darter
E. nigrum Rafinesque, 1820	Johnny Darter
E. pellucidum (Putnam, 1863)	Eastern Sand Darter ε
E. spectabile (Agassiz, 1854)	Orangethroat Darter
Family Sciaenidae (Drums)	
Aplodinotus grunniens Rafinesque, 1819	Freshwater Drum *

RESULTS AND DISCUSSION

The checklist includes 55 species. Of these, 48 were collected during my sampling in 1991 (Table 1). Thirteen species (Appendix 2) are reported as county records. Of the 13 county records, 12 species were previously known from the Little Wabash River drainage in other parts of Illinois. *Morone mississippiensis* is reported from the Little Wabash River drainage for the first time. Records reported here for five species - *Lythrurus fumeus, Minytrema melanops, Aphredoderus sayanus, Etheostoma asprigene*, and *Aplodinotus grunniens* - are the northern most records for the species in the Little Wabash River drainage. *Etheosotma asprigene* was not recollected during 1991, and its status is not certain. The other four species may have expanded their ranges northward. Three others, *Gambusia affinis, Lepomis microlophus*, and *Morone mississippiensis*, may also have done so, but it is also possible that these species were introduced because the first is commonly introduced for mosquito control while the latter two are sometimes stocked as a sport fish. Six species (Appendix 3) were not recollected. One species, *Etheostoma asprigene*, is included based on a museum record but was not recollected in 1991 nor was it reported by Smith, 1979.

The seven species that were not recollected, with the possible exception of *Etheostoma aprigene*, respond negatively to increased siltation (Smith, 1979). At the same time, at least four of seven species thought to have expanded their ranges, namely, *Lythrurus fumeus, Ameiurus natalis, Aphredoderus sayanus*, and *Aplodinotus grunniens*, prefer mud or silt bottoms (Smith, 1979). Because collecting effort could not be standardized among years and collectors, it is uncertain whether species not recollected are extirpated or were just missed. It is also possible that species not previously collected may have been present but missed. What is known is that the clear-water species not recollected in 1991 are now uncommon enough to be missed and that the species preferring silt or mud bottoms are now common enough to be collected.

The net change in diversity among Effingham County fishes is difficult to measure because there are no previously published studies to which the 1991 findings can be compared and because collecting efforts have not been standardized. However, if Smith (1979) is adopted as a starting place, then a base line can be reconstructed. Of the 55

species in the checklist, Smith (1979) reported records for 42. He did not report UMMZ records for *Etheostoma asprigene, Minytrema melanops*, and *Lepomis gulosus*. If these are added to Smith's (1979) reported records, a pre-1979 total of 45 species results. Smith (1979) also reported records both north and south of Effingham County for *Ameiurus natalis, Ictalurus punctatus*, and *Pomoxis annularis*. Adding these three to the pre-1979 total yields 48 species. Considering 48 species as a pre-1979 base line, the impact of human activities including siltation and stocking of exotic species can be estimated. Seven species (*Etheostoma asprigene* and the six included in Appendix 3) may be extirpated or are at least uncommon enough to be missed. If these are deducted from the pre-1979 total of 48 species, then 41 of those species remain in the Little Wabash River drainage in Effingham County. This is a net reduction in diversity of 14.58%. However, seven other species have either expanded their ranges into Effingham County or at least become common enough to be collected by the efforts expended. These are called post-1979 species. It must be acknowledged that all of these species may have been present prior to 1979 but were simply missed by the collecting efforts reported in Smith (1979). In any case, net species diversity has not changed appreciably from what it was when Smith (1979) reported his results.

ACKNOWLEDGEMENTS

This study was initiated as a project for a course, Biology of the Lower Vertebrates, at Illinois State University; I thank Lauren E. Brown for providing collection and preservation supplies. Larry M. Page provided records from the INHS and helped with identifications. Brooks M. Burr provided records from SIUC. D. W. Nelson provided UMMZ records. For field assistance I thank Moynell M. Tucker, Joshua Tucker, Jacob Tucker, Jeannie Tucker, Sanford Field, Jr., Sanford Field, III, Neil R. Miller, Jacob H. L. Miller, and Thad Brockett. John P. Ballenot, Brooks M. Burr, Robert Maher, Christine Mayer, Mark Sabaj, and Charles Theiling made many useful comments on the manuscript.

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APPENDIX 1: Localities Sampled

1. Wren Drive area of Lake Sara, 7 miles W of Effingham, T8N, R5E, sec. 15; 2. Little Wabash River at junction with county road 1975N, T9N, R6E, sec. 30; 3. Little Wabash River at junction with county road 1000N, T7N, R5E, sec. 11 and 14; 4. Little Wabash River at junction with Ill. routes 32 and 33, T8N, R5E, sec. 13; 5. Little Wabash River at junction with Fayette Avenue, county road 1375N, T8N, R5E, sec. 25; 6. Little Wabash River at junction with Ford Avenue, county road 1175E, T8N, R5E, sec. 13 and 24; 7. Little Wabash River at junction with US route 40, T8N, R5E, sec. 36; 8. Little Wabash River at junction with county road 900E, T7N, R5E, sec. 22; 9. Little Wabash River at junction with county road 300N, T6N, R6E, sec. 17 and 20; 10. Little Wabash River at junction with Ill. route 37, T6N, R5E, sec. 1; 11. Shoal Creek, 1.5 miles E of junction with Ill. route 32, T9N, R5E, sec. 26; 12. Shoal Creek at junction with Ill. route 32, T9N, R5E, sec. 34 and 35; 13. North Fork of Shoal Creek at junction with county road 2000N, T9N, R5E, sec. 25; 14. Green Creek, 0.25 mile S of county road 1800N, T8N, R6E, sec. 6; 15. Green Creek at junction with county road 1400E, T9N, R6E, sec. 32; 16. Green Creek at junction with county road 1975N, T9N, R6E, sec. 28; 17. Green Creek at junction with county road 1800N, T8N, R6E, sec. 5; 18. Lilly Creek at junction with US route 40, T7N, R5E, sec. 4; 19. Limestone Creek 0.5 mile W of county road 750E, T6N, R5E, sec. 18; 20. Big Creek at junction with county road 675E, T7N, R5E, sec. 30; 21. Second Creek at junction with county road 650E, T7N, R5E, sec. 19; 22. Fulfer Creek at junction with county road 725E, T6N, R5E, sec. 8; 23. Coon Creek at junction with county road 225N, T6N, R6E, sec. 19; 24. Salt Creek at junction with Crystal Club Road, county road 1600E, T8N, R6E, sec. 14; 25. Salt Creek at junction with county road 500N, T6N, R6E, sec. 4; 26. Little Salt Creek at junction with Ill. route 33, T7N, R7E, sec. 5; 27. Bishop Creek at junction with US route 45, T6N, R6E, sec. 21.

APPENDIX 2: County Records

Localities for 1991 collections and for collections made prior to 1991 but not reported by Smith (1979), and comments for species reported from Effingham County for the first time are as follows:

Ameiurus natalis

Current study: Locality numbers 1 (INHS 29440) and 27 (INHS 29446); also observed but not collected at locality 4. Nearest previously published record is for Clay County (Smith, 1979). However, the species has been reported from all other counties bordering Effingham County and from the Little Wabash River drainage north and south of Effingham County (Smith, 1979).

Aphredoderus sayanus

Current study: Locality numbers 19 (INHS 29438), 21, 23 (INHS 29441), and 27 (INHS 29447). Nearest previously published record is for Clay County (Smith, 1979). Effingham County localities are the northern most records for the species from the Little Wabash River drainage.

Aplodinotus grunniens

Current study: Locality number 10 (INHS 29439). Nearest previously published locality is in Wayne County (Smith, 1979). The Effingham County locality is the northern most record for the species from the Little Wabash River drainage.

Etheostoma asprigene

Current study: None collected. Museum record:UMMZ 105938 from an unnamed tributary near Mason, Illinois. Previously reported from Clay County by Smith, 1979. Its status in Effingham County is not certain. No specimens were found in likely habitats in the southern portion of the county from which the UMMZ specimen was collected in 1937. The species is included in this appendix because it had not been previously recorded for Effingham County.

Gambusia affinis

Current study: Locality numbers 1, 5, 7, 8, and 10. Museum record:SIUC unnumbered from locality 7. Nearest previously published record is for Clay County. The Effingham County records are the northern most records for the species from the Little Wabash River drainage.

Ictalurus punctatus

Current study: Locality numbers 1, 3, 4, 6, and 8. Museum records:INHS 59293 from locality 25 and INHS 59134 from locality 10. The species is widely stocked and previously reported from the Little Wabash River drainage both north and south of the Effingham County records.

Lepomis gulosus

Current study: Not taken, but observed at locality 1. Museum record:UMMZ 105941 from an unnamed tributary near Mason, Illinois. Nearest previously published record is

from Clay County. The Effingham County record is the northern most record for the species from the Little Wabash River drainage.

L. microlophus

Current study: Localities 1, 4, 12, 13, and 14. Museum record:INHS 59137 from locality 10. The nearest previously published record is from Fayette County (Smith, 1979). The Effingham county records are the northern most records for the species from the Little Wabash River drainage.

Lythrurus fumeus

Current study: Localities 25 and 27. Museum record:SIUC 7435 from locality 2. The nearest previously published record is from Clay County (Smith, 1979). The Effingham County records are the northern most records for the species from the Little Wabash River drainage.

Minytrema melanops

Current study: Localities 3 and 10. Museum record:UMMZ 105934 from an unnamed tributary near Mason, Illinois. The nearest previously published record is for Clay County (Smith, 1979). The Effingham County records are the northern most records for the species from the Little Wabash River drainage.

Morone mississippiensis

Current study: Locality 10 (INHS 29443). The nearest previously published record is for Coles County in the Embarras River drainage. The Effingham County record is the first record for the species in the Little Wabash River drainage. This species is occasionally stocked as a sport fish, and the specimen may be an escapee from a stocking.

Pimephales vigilax

Current study: Localities 9, 10, and 26. Museum records:INHS 59159 from locality 5; SIUC 13383 from locality 7; INHS 59291 from locality 25. The nearest records are from Fayette County to the west and Shelby County to the north (Smith, 1979). The Effingham County records represent the southern most records for the species from the Little Wabash River drainage. This species is widely used as a bait fish, and the Effingham County records may represent bait releases.

Pomoxis annularis

Current study: Locality 9; also observed but not collected at localities 1 and 7. Museum record:SIUC 13390 from locality 7. The White Crappie is widely stocked and has been reported from both north and south of Effingham County in the Little Wabash River drainage (Smith, 1979).

APPENDIX 3: Species Not Recollected

Nocomis biguttatus

The hornyhead chub is known from a single record from locality 5 (INHS 7505) collected in 1950. The locality was subsequently visited once by an INHS crew (August 1990), once by SIU collectors (October 1982), and twice during the current study. It seems likely that this chub no longer occurs in Effingham County.

Notropis boops

This species has been collected twice in Effingham County: in 1950 at locality 5 (INHS 7507) and in 1960 at locality 10 (INHS 7534). SIU collectors visited locality 5 in 1982 and did not collect the species. I visited the locality twice in 1991 and did not recover the species. INHS collectors revisited locality 10 in May 1964 and August 1990 but did not report the species. During my study this locality was sampled three times, but the bigeye shiner was not found. It seems likely that this species is now extirpated from Effingham County.

Hybopsis amblops

This species is known from locality 5 (INHS 7504) where three specimens were collected in July 1950. Since then the location has been sampled four times by INHS, SIU, and myself without producing any additional specimens of the bigeye chub. The species appears to be extirpated from Effingham County.

Percina phoxocephala

This species of *Percina* had previously been collected at locality 10 in 1964 (INHS 7554), locality 25 in 1970 (INHS 7678), and locality 7 in 1986 (SIUC 13395). During the current study no specimens of the slenderhead darter were collected. The species does certainly occur in neighboring Clay County because specimens were collected in 1991 at two locations along the Little Wabash River by myself. It is likely that this species still occurs in Effingham County but that it is rare or at least less common than it was previously.

Etheostoma chlorosomum

The bluntnose darter is known from two records. One of these, INHS 59304, sixteen specimens collected in 1877, is without precise locality data. The other, UMMZ 105937, is from a "small trib of Little Wabash River, near Mason" and was collected in 1937. No additional specimens have been recovered despite intensive collecting by INHS, SIUC, and myself. The species does still occur in Clay County and was found to be common at one location in that county. It is, however, likely extirpated from Effingham County.

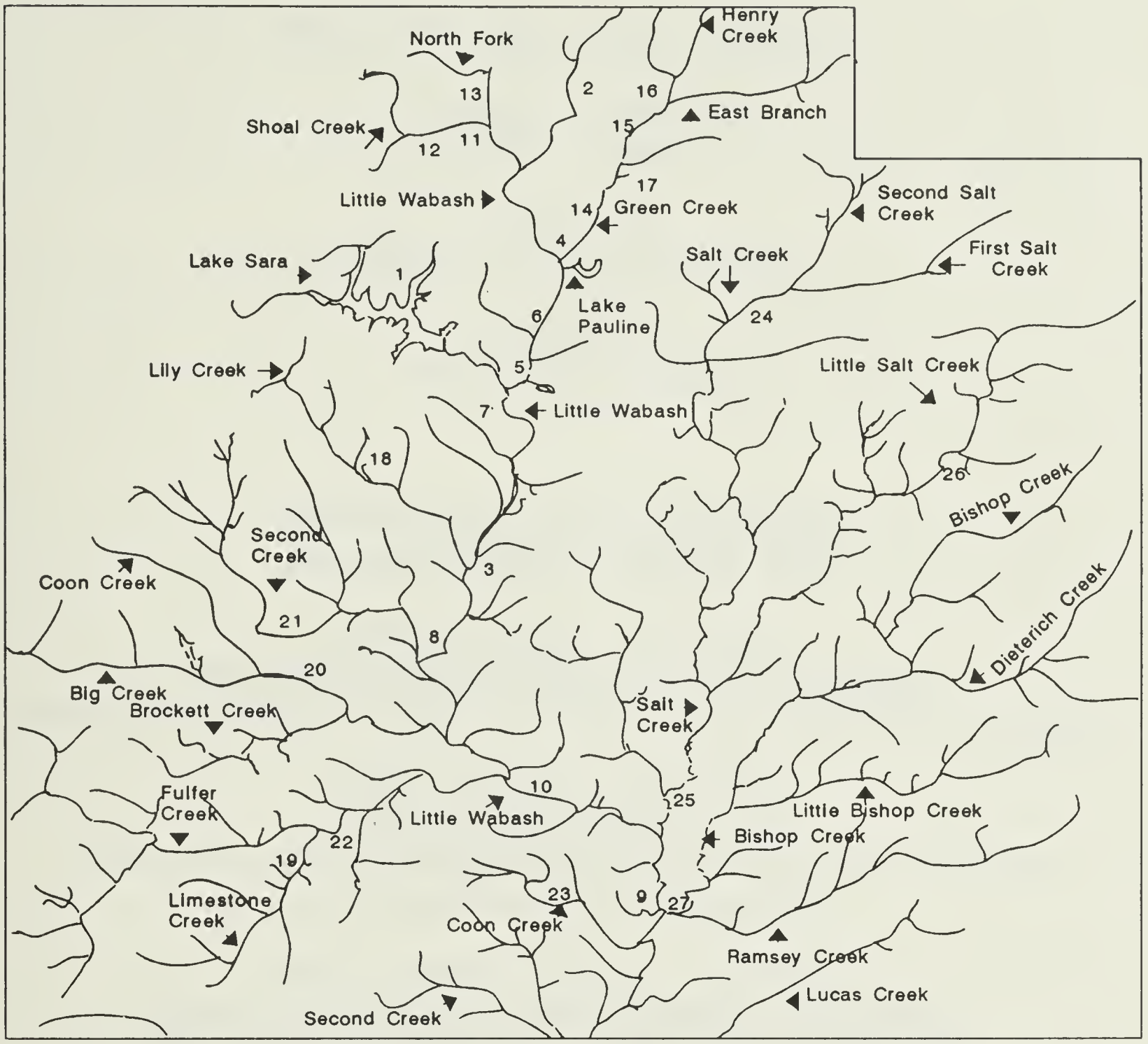
Etheostoma pellucidum

This darter was collected once at locality 5 in 1950 (INHS 7520). It has not been collected since, though this locality has been visited no fewer than four times since then. Locality 4, which was visited six times during the current study, appears to be ideal habitat for this sand-loving darter, yet no specimens were recovered. It is almost certain that the species is now extirpated from Effingham County.

Table 1: Distributional checklist of fishes collected in the Little WabashRiver drainage in Effingham County for 1991 collections.

Locality:	1	2	3	4	5	6	7	8	9	10 11	12 13	14 15	16 17	18 19	20 21	22 23	24 25	26 27
Dorosoma cepedianum	x																	
Cyprinus carpio	x																	
Notemigonus crysoleucas																		x
Semotilus atromaculatus				x		x	x	x		x	x	x	x	x	x	x	x	x x
Campostoma anomalum		x		x		x	x	x		x	x	x	x	x	x	x	x	x x
Phenacobius mirabilis				x	x		x	x				x		x		x		x
Luxilus chrysocephalus		x		x		x	x	x	x	x	x	x	x	x	x	x	x	x x
Lythrurus fumeus																	x	x
L. umbratilis			x	x	x		x	x	x	x	x	x	x	x	x	x	x	x x
Cyprinella spiloptera		x	x	x	x	x	x	x	x	x		x	x	x		x		x
C. whipplei		x	x	x		x	x	x	x	x		x		x				x
Pimephales notatus		x		x	x	x	x	x		x	x	x	x	x	x	x	x	x x
P. vigilax									x	x								x
Notropis ludibundus		x	x	x	x	x	x	x			x		x	x	x		x	x
Ericymba buccata		x	x	x	x	x	x	x			x	x	x	x	x	x	x	x
Carpioides cyprinus				x								x		x	x			
Catostomus commersoni		x	x								x							
Minytrema melanops			x						x									
Erimyzon oblongus				x						x	x	x	x	x	x	x	x	x x
Hypentelium nigricans		x		x	x		x											
Moxostoma erythrurum		x		x	x													
M. macrolepidotum			x				x											
Ictalurus punctatus	x		x	x		x		x										
Ameiurus melas	x			x						x	x	x						x
A. natalis	x																	x
Noturus gyrinus									x									
N. miurus		x		x		x											x	
Aphredoderus sayanus														x	x	x		x
Fundulus notatus	x	x	x	x	x		x	x	x	x		x	x	x	x	x	x	x x
Gambusia affinis	x				x		x	x		x								
Morone mississippiensis										x								
Pomoxis annularis	x								x									
Micropterus punctulatus		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
M. salmoides	x																	
Lepomis cyanellus	x	x	x	x	x	x				x	x	x			x			x x
L. gulosus	x																	
L. humilis	x									x								
L. macrochirus	x		x		x		x	x	x	x	x		x	x		x	x	x x
L. megalotis	x	x	x	x	x	x	x	x	x						x		x	x x
L. microlophus	x			x						x	x	x						
Percina caprodes				x			x											
P. maculata		x		x	x		x		x									
P. sciera			x	x			x											
Etheostoma blennioides		x		x		x	x											
E. gracile															x			
E. nigrum		x		x	x	x	x		x		x	x	x		x	x	x	x x
E. spectabile		x		x		x		x		x	x	x	x	x	x	x	x	x x
Aplodinotus grunniens									x									
Total number of species:	15	18	15	28	16	22	16	17	9	17	13	14	11	17	13	10	15	10	15	16	11	10	15	13

Figure 1. Little Wabash River drainage in Effingham County. Details on each collecting station (numbers) are in Appendix 1.



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Botany Division - 2nd Place

K.J. Roberts, Illinois State University
An Examination of the Relationship Between Garlic Mustard (*Alliaria petiolata*) and Vesicular-Arbuscular Mycorrhizal Fungi

Health Sciences Division - 1st Place

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Identification of CD_4+ Cytotoxic Lymphocytes that Recognize Foreign MHC Class I Antigens by an Indirect Pathway

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Characterization of Deletion Sites in a Human Colagen-Like Locus

Devaka K. Weerakoon, Illinois State University
Role of Entactin on Adhesion and Migration of Macrophages

Pratumtip Boontrakulpoontawee, Illinois State University
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Transactions of the Illinois State Academy of Science
Volume 87 (1994)

CONTENTS

Academy of Science Editorial Information ..... inside front cover

Botany Papers

Gorsic, J.
Hereditary Variation in *Collinsia concolor* 1

Vaultonburg, David L. and Charles L. Pederson
Spatial and Temporal Variation of Diatom Community Structure in Two East-Central Illinois Streams 9

Environmental Science Papers

Petersen, Chris E.
The Extent of Anthropogenic Disturbance on the Aquatic Assemblages of the East Branch of the DuPage River, Illinois, as Evaluated Using Stream Arthropods 29

Zoology Papers

Armbruster, Jonathan W.
Early Season Nesting Success of Mourning Doves (*Zenaida macroura*) in Central Illinois 37

Dyer, William G.
Some Helminths of the Racer, *Coluber constrictor*, and the Eastern Hognose Snake, *Heterodon platirhinos*, in Southern Illinois 43

Pigage, Jon C. and Helen K. Pigage
The Western Harvest Mouse (*Reithrodontomys megalotis*) Moves to Northeastern Illinois 47

Reck, Michelle and Thomas E. McQuistion
The Anticoccidial Effects of Amprolium, Monensin and Sodium Sulfamethazine in Farm-Reared Chukar Partridges (*Alectoris graeca*) in Illinois 51

Roseberry, John L. and Larry M. David
The Conservation Reserve Program and Northern Bobwhite Population Trends in Illinois 61

Taylor, Christopher A., Brooks M. Burr, and Kenneth M. Cook
Status and Distribution of Three Rare Illinois Fishes: Blacktail Shiner (*Cyprinella venusta*), Northern Starhead Topminnow (*Fundulus dispar*) and Cypress Darter (*Etheostoma proeliare*) 71

Thurow, Gordon R.
Experimental Return of Wood Frogs to West-Central Illinois 83

Tucker, John K.
Checklist of the Freshwater Fishes of the Little Wabash River Drainage in Effingham County, Illinois with Comments on Possible Changes in Faunal Composition 99

Academy Notes 111

Contributor Information ..... inside back cover

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.R338
v. 87
#3-4

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TRANSACTIONS of the ILLINOIS STATE ACADEMY OF SCIENCE

Volume 87, Numbers 3 and 4 1994

ILLINOIS STATE ACADEMY OF SCIENCE
Founded 1907

Affiliated with the
ILLINOIS STATE MUSEUM, Springfield

ISSN 0019-2252
PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

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Transactions of the Illinois State Academy of Science
(1994), Volume 87, 3 and 4, pp. 113-115

The Occurrence of Four Rare Plants in Cook County

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ABSTRACT

Geranium bicknelli Britt. and *Chamaesyce polygonifolia* (L.) Small, both state endangered, were recently found in Cook County where no extant populations had been known. While known in Cook County from one station each, additional populations of state threatened *Cakile edentula* (Bigelow) Hook. ssp. *lacustris* (Fern.) Hulten and state endangered *Ammophila breviligulata* Fern. were also discovered.

RESULTS AND DISCUSSION

Populations of *Geranium bicknelli* Britt. (northern cranesbill) and *Chamaesyce polygonifolia* (L.) Small (seaside spurge), both state endangered, were recently discovered in Cook County. Prior to these finds, no extant stations for the two species were known from the county; all existing sites previously known in Illinois are located within Lake County (Herkert, 1991). In addition, new populations of *Cakile edentula* (Bigelow) Hook. ssp. *lacustris* (Fern.) Hulten (sea rocket), a state threatened species, and *Ammophila breviligulata* Fern., a state endangered species, were also found in Cook County. Each species had previously been represented by only one station in Cook County (Illinois Natural Heritage Database). Voucher specimens or photographs have been deposited at the Morton Arboretum.

Geranium bicknelli

In June 1993, 29 of these plants were discovered on a recently-burned railroad right-of way in Northbrook growing in close proximity to *G. carolinianum* L.

Cakile edentula ssp. *lacustris*

On September 19, 1993, *C. edentula* was found on the Montrose Harbor beach on Chicago's lakefront. Alan Stokie (personal communication) indicated that he had observed the species there in the late 1980's and counted six individual plants in September 1992. This information prompted a systematic search of Cook County beaches which revealed 23 populations of *C. edentula*, two of which are quite large: 150

at South Boulevard Beach in Evanston and 240 at Rainbow Beach in Chicago. (See Table 1)

Chamaesyce polygonifolia

The above mentioned beach survey also resulted in the discovery of 13 populations of this species, the three largest of which are 250 at Tower Beach in Winnetka, 600 at Rainbow Beach in Chicago, and 200 south of the South Water Filtration Plant in Chicago. (See Table 1).

Ammophila breviligulata

Three small populations of this plant were discovered in Evanston (where they may have been planted as part of a dune restoration), Winnetka, and Wilmette.

The greatest threats to the continued existence of the above three plants are beach cleaning, vehicular trespass, and trodding by thousands of human feet. It is interesting that many of the populations are afforded protection from these activities by their locations near boat racks, retaining walls, and other man-made structures, on beaches with limited access, and amidst *Cenchrus longispinus* (Hack.) Fern.

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Table 1. Number of populations and individuals of *Chamaesyce polygonifolia* and *Cakile edentula* ssp. *lacustris* in Cook County.

	Chamaesyce polygonifolia		*Cakile edentula*	
	Populations	Individuals	Populations	Individuals
Glencoe:	1	(19)	1	(5)
Winnetka:	4	(19)(4)(250)(50)	6	(14)(5)(3)(8)(9)(3)
Wilmette:	2	(30)(23)	6	(21)(10)(4)(1)(29)(10)
Evanston:	4	(5)(2)(6)(19)	7	(150)(1)(90)(3)(12)(1)(12)
Chicago:	2	(600)(200)	3	(12)(240)(11)

Transactions of the Illinois State Academy of Science
(1994), Volume 87, 3 and 4, pp. 117-133

Impacts of Settlement on Floodplain Vegetation at the Confluence of the Illinois and Mississippi Rivers

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ABSTRACT

Government Land Office (GLO) survey records were used to reconstruct the presettlement floodplain landscape at the confluence of the Illinois and Mississippi rivers. Presettlement prairie and forest land covers were determined by digitizing GLO plat maps using a computerized geographic information system (GIS). A case history of land cover change was determined by comparing this presettlement map to GIS land cover maps for 1903, 1935, and 1975. Data from witness trees and current forest samples were used to compare presettlement and present forest composition and structure. Results indicate that approximately 56% of the presettlement floodplain was forested, while 41% was prairie. The presettlement forests were generally open (86.8 stems/ha) and consisted of several dominant tree species. In contrast, the present forest is more dense (489 stems/ha) and is dominated by silver maple (*Acer saccharinum*). Early settlement had little affect on the spatial distribution of forest cover, but river impoundment in 1938 reduced forests to approximately 35% of the floodplain. Prairies were converted to agriculture during the middle 1800s and now occupy only 6% of the floodplain. Overall, the floodplain landscape and vegetation patterns present today are very different from their presettlement conditions. The major activities responsible for these changes were timber harvesting, agriculture, and river impoundment.

INTRODUCTION

The Illinois and Upper Mississippi River valleys have been so extensively modified that it is difficult to imagine natural landscapes as they appeared before Euro-American settlement. Examples of human alterations to the Upper Mississippi River (UMR) valley include deforestation, agricultural land development, draining of wetlands, levee construction, urban expansion, and river impoundments (U.S. Army Corps of Engineers [COE], 1980; Fremling et al., 1989; Bhowmik, 1993). Despite these impacts, the UMR

retains a high degree of biological integrity because it provides a diversity of habitats that are essential to a variety of plants and animals (Upper Mississippi River Basin Commission, 1982; COE, 1991; National Research Council, 1992; Sparks, 1992). However, natural floodplain landscapes were so quickly modified following settlement that baseline data regarding pristine conditions are lacking. Therefore, information concerning natural conditions, as well as the impacts that have led to present conditions, should be valuable to those involved in the management, preservation, and restoration of the UMR.

The Mississippi and Illinois River floodplains in west-central Illinois consisted of prairie and forest communities before Euro-American settlement (Finiels, 1797; Allen, 1870). Early settlers were attracted to this western frontier by the high fertility of the land, its vast resources, and the transportation network provided by the Mississippi River and its tributaries. As a result, most of the natural floodplain prairies were converted to agricultural fields. In contrast, many floodplain forests remain because they were more flood prone and thus less suitable for agriculture. Nonetheless, these forests were often intensively logged for lumber and for fueling steamboats (Havighurst, 1964; Donovan, 1966; Ward, 1973; Williams, 1980).

While floodplain landscapes of the UMR valley were being altered by early settlement, the mainstem rivers were also being modified to improve navigation. In the mid-1800s, river projects were limited to dredging and snag removal. Later, demands for a more reliable commercial navigation system prompted large-scale river control projects (O'Brien et al., 1992). The most notable project was the construction of our present-day navigation system. During the 1930s, a series of 27 locks and dams were built between St. Louis, Missouri and St. Paul-Minneapolis, Minnesota (except for the Keokuk, Iowa, dam built in 1913). Another series of 8 locks and dams were built along the Illinois River to Chicago, Illinois. The dams impound water to maintain a minimum 2.7 m (9 foot) deep navigation channel.

An immediate result of each impoundment was the permanent inundation of low-lying floodplain habitats bordering the river, especially those areas just upstream from each dam. Inundation replaced some floodplain forests and prairies with aquatic habitats (Yeager, 1949; COE, 1980).

Another important consequence of the navigation system was its alteration of the rivers' natural water level fluctuations. Hydrology is considered one of the dominant environment factors influencing tree species distributions and productivity in bottomland forests (Briscoe, 1961; Bedinger, 1978; Brown and Peterson, 1983). Navigation dams reduce mean annual river water level fluctuations (Grubaugh and Anderson, 1988), thus altering the conditions to which most floodplain tree species are adapted. While permanent inundation kills most trees species (Yeager, 1949), the long-term effects of impoundments and reduced annual flooding on the remaining forests are unclear. Recently, biologists working along the UMR have observed poor natural regeneration of native hardwoods such as pecan, hickories, oaks, and other important mast producing trees (Schnick et al., 1982).

Forest ecologists have long recognized the important information contained in GLO survey records for many regions of the United States (e.g., Cottam and Curtis, 1956; Anderson, 1970; Anderson and Anderson, 1975; Delcourt, 1976; Rogers and Anderson, 1979; Leitner and Jackson, 1981; Barnes, 1989; Iverson et al., 1989; Thomas and Anderson 1990; and others). The records have proven to be one of the best sources of information regarding natural presettlement vegetation patterns for two primary reasons. First, most GLO surveys were conducted before Euro-American settlement had significantly altered the landscape. Second, the survey methods employed by the GLO represents a systematic form of sampling that provides quantifiable data.

In this study, GLO survey records were used to reconstruct the presettlement floodplain vegetation patterns at the confluence of the Illinois and Mississippi rivers. Forest data and GIS maps are used to present a 170 year case history of landscape and vegetation changes within the study area. Our intention is to provide a better understanding of the presettlement floodplain conditions within the UMR, as well as the effects of human activities upon the natural floodplain landscape.

STUDY AREA

The study area is located on the floodplain at the confluence of the Illinois and Mississippi rivers at the southern tip of Calhoun County, Illinois. The area is 3388 ha (8371 acres) and includes areas known locally as Calhoun Point and Swan Lake (Fig. 1). Its location is mid-reach between Mississippi River Locks and Dams 25 and 26. Here, river water level fluctuations are minimized because dam operating procedures maintain target water levels at a river gage at Grafton (Fig. 1).

Topography is nearly level, with scattered ridges and flats ranging in elevation between 127.7 m (419 ft) and 131.0 m (430 ft) above mean sea level. The predominant soil type on the lowest elevations is Beaucoup silty clay loam, characterized as poorly drained silty soil formed in alluvium. At slightly higher elevations, soils are either Tice silt loam or Wakeland silt loam, characterized as somewhat poorly drained soils. Although much less extensive, the Sharpy sand series, characterized as rapidly drained sandy soils, occur on some shorelines, sandbars, and natural levees (U.S. Department of Agriculture, 1989).

Calhoun Point is subject to occasional flooding by both the Illinois and Mississippi rivers. The area consists of several backwater lakes, sloughs, and ephemeral ponds with much of the land cover in bottomland hardwoods. Swan Lake is subject to occasional flooding by the Illinois River. Although 1060 ha (2619 acres) of the historical floodplain has been permanently inundated (since closure of Lock and Dam 26 in 1938), 527 ha (1302 acres) of the surrounding floodplain remains in bottomland hardwoods.

METHODS

GLO Survey Records and Current Forest Sampling

The township lines of Calhoun County were surveyed in 1815 and the interior section lines were completed in 1817. A post was set and two witness trees were blazed at section corners, quarter section corners, and on river banks in timbered lands. Species names, distances, diameters and bearings were recorded in field notes. If trees were not

present or near a corner, the surveyors erected a mound and noted "prairie" in their field notes. In addition to witness trees, trees encountered on section lines were similarly recorded in the field notes. At the end of each section line, the deputy surveyor recorded a brief description of the vegetation, terrain, any unusual features, and agricultural suitability. Presettlement forest composition and structure were determined by compiling witness tree data from these GLO survey records, which resulted in a sample of 97 trees.

Instructions given to GLO surveyors was that the first witness tree be nearest the post, and the second be the next nearest tree in an opposite direction (Tiffin, 1815). However, in the case of our study area, there was no consistent pattern in the location of the second witness tree after the first witness tree was recorded. This was probably due to the many river banks sites at which the second tree could not occur in an opposite direction because of the presence of the Illinois or Mississippi rivers. We therefore used the shortest witness tree distance as the Q_1 distance of the quarter point method for computing the square root of the mean area (Cottam and Curtis, 1956).

Using the Q_1 distance to estimate tree density at each surveyed corner, forest, savannah, and prairie communities were determined by criteria established by Anderson and Anderson (1975). Corners with more than 46.9 trees/ha were considered forest. Corners with 46.9 trees/ha or less, but more than 0.5 trees/ha were considered savannah. Corners with 0.5 trees/ha or less, or where surveyors erected a mound, were considered prairie. The percent frequency of corners established in each vegetation type was then calculated.

Since the study area lies between two major rivers, there were many points surveyed along the river banks. These points were not considered in computing the overall percent frequencies of vegetation types because more timbered land naturally occurred along the river banks. Including these points would skew results because they were surveyed as a function of river locality rather than a distance measurement. Rather, we evaluated the river bank corners separate from the corners surveyed within the interior of the study area.

Additional GLO surveys were conducted in 1826 and 1842 to measure the meanders of the Illinois and Mississippi rivers, respectively. The witness tree data in these survey records were not suitable for analysis because they did not cover the entire study area. However, the deputy surveyor's line descriptions helped determine historic human impacts on the floodplain environment in the decades immediately following the original surveys of 1815 and 1817.

A current forest survey of the study area was conducted during the spring of 1992 using the quarter point method (Wenger 1984), which closely approximates the GLO survey methods. Tree measurements were obtained from samples sites at 156 random locations throughout the forested floodplain, resulting in a sample of 628 trees.

Mean diameter breast height (dbh), relative density, relative dominance, and importance value were calculated for each taxa to compare presettlement and present forest composition.

Mapping

A geographic information system (GIS) map of the presettlement floodplain was prepared from GLO survey data and plat maps. Because the GLO surveyors recorded distances on each section line when vegetation patterns changed (e.g., forest to prairie), we were able to locate these points on modern U.S. Geological Survey quadrangle maps. Plat maps were then used to determine the boundaries (connections between points) of three land cover types mapped at the time of the original surveys; forest, prairie, and water. These land cover types were digitized after registering the map to a digitizing tablet using universal transverse mercater (UTM) coordinates at the intersection of several section corners. Enough known UTM coordinates were used to insure that standard deviations were within acceptable limits of the GIS application.

The GLO survey plat maps of the study area contained sufficient detail to map the land covers described above except the outline of presettlement Swan Lake. In their notes however, surveyors did describe the presence of a lake and mapped a portion of its southern boundary. In order to complete our presettlement map, we incorporated a 1935 outline of Swan Lake as the presettlement condition. We believe this to be the best representation of the presettlement floodplain despite this small discrepancy.

Spatial changes in land cover over time were determined by comparing the presettlement map to GIS land cover maps for 1903 (Woermann, 1903), 1935, and 1975 (U.S. Fish and Wildlife Service, 1991). Land covers are presented as percent of total area.

Hydrology

Historic river water level data, obtained from the Grafton gage (Fig. 1), were used to evaluate hydrologic changes at the study site resulting from the completion of Lock and Dam 26 in 1938. The U.S. Army Corps of Engineers has maintained a daily record of water levels at this gage station since 1879. Predam and postdam mean annual hydrographs were made by averaging water levels by day of year.

RESULTS AND DISCUSSION

Presettlement Vegetation (1817)

Our presettlement GIS map shows that forests covered approximately 56% of the floodplain (Fig. 2A). This result compares closely with 56.2% of corners established in both forest and savannah categories. The GLO surveyors clearly did not distinguish between forest and savannah communities when constructing their plat maps in this area.

Nineteen tree taxa were recorded by the GLO surveyors (Table 1). The taxa with the highest importance values (IV > 20) were hackberry (*Celtis occidentalis*), pecan (*Carya illinoensis*), elm (*Ulmus* spp.), willow (*salix* spp.), and cottonwood (*Populus deltoides*).

Average tree density was estimated to be 86.8 trees per hectare. This low density is one indication that the presettlement forest was a somewhat open landscape with widely spaced trees. Another indication is that 66.6% of corners surveyed with witness trees were determined to be in savannah. GLO surveyors recorded savannah conditions as "scattering timber" and "thinnly timbered" in their line descriptions. Savannah communities were most often encountered in transitions zones between prairie and forest

communities. For example, a typical line description reports: "Leave scattering timber and enter prairie." However, these conditions were not limited to the floodplain interior. Of the corners established along the river banks, 47.8% were determined to be in savannah.

More recent evidence of the open nature of the presettlement forest was also alluded to by Yeager (1949) in 1937. In his predam study of Calhoun Point, he noted the presence of some old growth stands that contained over mature and large multi-branched maples, elms, oaks, and sycamores. These trees were probably remnants of the presettlement forest because their old age and branching habit are indicative of former open forest conditions.

Prairie communities covered approximately 41% of the presettlement floodplain (Fig. 2A) and this estimate compares closely with the percent frequency of corners established in prairie (37.8%). Although GLO surveyors did not identify any of the plant species they observed, they did apply the terms "wet" and "dry" to the various line descriptions of the floodplain prairies. One surveyor noted, for example: "Land level and rather wet-bottom prairie too wet for cultivation....Land gently rolling, good dry prairie fit for cultivation." Today, similar soil moisture modifiers are still used to delineate prairie communities (i.e., wet prairie, dry sand prairie, wet meadow, etc.). Based on the inferred moisture gradient, topography, and soils, at least three distinct prairie communities existed within the presettlement floodplain: wet, wet-mesic, and mesic prairies. Studies of relic floodplain prairies are good sources of information about the composition and species associations of natural prairie communities (see Zawacki and Hausfater, 1969; Nelson, 1987). The following description by Turner (1934) of a relic prairie along the lower Illinois River is important to note because it agrees closely with the GLO prairie descriptions: "This forest type merges into a grass association, at first on the hydric side of mesophytism, but giving way in turn, as the elevation of the floodplain increases, to a mesic grass association."

The maintenance of natural floodplain prairie communities in the Midwest has been attributed to disturbances by fire, flooding, sedimentation, and erosion (Nelson, 1987). Fire has long been considered a principal component of mid-western prairie ecosystems (Englemann, 1863; Allen, 1870; Anderson, 1970), and most fires are considered to have been intentionally set by Native Americans (Gleason, 1913; Ladd 1991). The open nature of the presettlement forest (86.8 trees/ha) might indicate that fire was also an important component of UMR floodplain ecosystems.

Impacts during Early Settlement (1817-1903)

The field notes of the original GLO surveys (1815-1817) contained no references to settlers within the study, but later surveys contained some information about settlement and timber harvesting. During the river meander survey of 1826, the deputy surveyor noted on the Mississippi River bank: "Timber mostly all cut down near the river bank by the settlers living here, but find a black oak stump said to be former lone bearing tree by the present settlers." At another nearby corner he noted: "re-establish (corner) in its former position from the remains of the former witness trees. The bur oak is fallen by decay and the black oak cut down." These comments indicate that settlement began soon after the original land surveys and that settlers were actively harvesting timber.

After 1830, steamboat traffic on the UMR system increased steadily, and the demand for fuelwood became enormous. Because abundant timber lined the river banks, steamboat commerce was not limited by any lack of fuel (Havighurst, 1964). Woodyards became a booming bussiness and many river bank farmers supplemented their incomes by harvesting and selling cordwood from bottomland forests (Havighurst, 1964; Donovan, 1966; Ward, 1973).

While measuring the meanders of the Illinois River in 1842, GLO surveyors noted "cut-off timber" in 50% of the line descriptions that ended at the river bank. For example, a typical record reports: "Timber pecan, maple, ash, elm, willows has been mostly cut-off." It is reasonable to assume that these cuttings were the result of steamboat fuelwood harvesting because they bordered the river bank and because no mention was made of nearby settlers or agricultural fields. Supporting evidence is provided by Williams (1980), who used the census of 1840 to map products from the eastern U.S. forests. He found that sales of cordwood were concentrated along major waterways due to demands from settlers and the hundreds of steamboats plying the rivers. Calhoun County ranked nationally among the highest in cordwood sales in 1840 (Williams, 1980).

Between 1817 and 1903, agriculture was the major impact that changed the presettlement floodplain landscape (Fig. 2A and 2B). During this time period, all of the higher elevation mesic prairie communities were converted to agriculture. The floodplain forests were exploited during this same time period but did not change much in their spatial distribution. Harvested areas were presumably quickly revegetated. Settlers were probably reluctant to clear forests for agriculture because these lands were more susceptible to flooding than the higher elevation mesic prairies. Surveyors in 1817 applied the term "overflows" to 76% of the line descriptions of the presettlement forest.

Impacts due to Impoundment (1935-1975)

GIS maps from 1935 and 1975 (Fig. 2C and 2D) show another period of dramatic land cover change, but the year of significance is 1938. During June of that year, the gates of Lock and Dam 26, located 32 km (20 miles) downstream, were closed for the first time. An immediate impact to the study area was a 2.6 m rise in water surface elevation (Fig. 3). This rise permanently inundated the lowest lying floodplain habitats and caused extensive timber mortality (Yeager, 1949). Consequently, forest cover was reduced from a predam distribution of 59% to a postdam distribution of 35%, while prairies were reduced from 8% to 6%.

Yeager (1949) studied impoundment effects on standing timber in the Calhoun Point area and found that nearly all trees subject to permanent inundation died within six years. At slightly higher elevations, where the effects of a perched water table were still evident, timber mortality ranged between 50 and 100% for all species except ash, river birch (*Betula nigra*), and cottonwood. Yeager (1949) also reported the rapid colonization of exposed mud flats by silver maple reproduction at four stems/ft^2. The ability of silver maple to exploit the new site conditions created following impoundment, along with its fast growth and intermediate shade tolerance, may explain its dominance in the present forest.

While river impoundment eliminated portions of forest and prairie within the study area, other hydrologic changes are important when considering the status of the remaining floodplain vegetation. Prior to impoundment, annual river water level fluctuations were much more dynamic than after impoundment. The predam mean annual hydrograph exhibits a pronounced spring and autumn rise in water levels, with periods of very low flow occurring in summer and winter (Fig. 3). Presently, the degree of annual flooding and drying has been reduced due to dam operating procedures that maintain high target water levels (Fig. 3). This hydrologic change has eliminated the period of very low flow during the growing season to which many floodplain tree species are adapted. Consequently, soil moisture content throughout the year may be higher in some areas and could be a limiting factor in the growth and establishment of some species.

Present Vegetation (1992)

Eighteen taxa were recorded in 1992 from a sample of 628 trees (Table 1). The importance value of silver maple (86.3) is over four times higher than that of the next most important species, hackberry (19.7). Average forest density was estimated at 489 trees per hectare. Changes in species importance values and forest densities between the presettlement and present suggest a forest in recovery following one or more major disturbances.

Forest sampling conducted in 1990 at pools 8 and 13 of the Mississippi River and the LaGrange Pool of the Illinois River also show silver maple to be the most abundant floodplain species (Langrehr, 1990; Shay and Gent, 1990; Peitzmeier-Ramano et al., 1990). This dominance of silver maple in the present floodplain forests of the UMR system may be one of the most important indicators of forest change due to human activities. For example, the shallow rooting habit, intermediate shade tolerance, and prolific seed production of silver maple (Burns and Honkala, 1990) should favor its growth and establishment on sites that were affected by river impoundments. Saturated soil conditions caused by perched water tables, though not as harmful as inundation, can adversely affect the growth of many species. However, silver maple seedlings are very tolerant of saturated soils, and height growth is even enhanced (Hosner and Boyce, 1962). The increased importance, high relative density, frequency, and dominance of silver maple (Table 1) imply that this species will continue to be the most abundant species occupying the floodplain for some time.

Many species, such as hackberry, pecan, elm, willow, cottonwood and others (Table 1), have decreased in importance values since the presettlement. This indicates that reproduction and/or establishment of these species is poor. This is probably due to the lack of suitable site conditions, due to impoundment effects, as well as to a lack of an abundant seed source, due to past logging activities. Therefore, these species should continue to decline as a component of this floodplain forest.

Prairie communities currently occupy only 6% of the floodplain (Fig. 2D). Wet prairie communities that survived the agricultural boom in the mid-1800s were less affected than the forests by river impoundment in 1938. Although inundation destroyed some prairies, it created new prairie wetlands in other areas (Fig. 2C and 2D). Presently, high sedimentation in backwaters created by impoundment are reducing water depths at a tremendous rate (approx. 1.3 cm/yr)(Cahill and Steel, 1986; Grubaugh and Anderson,

1989; Roseboom et al., 1992; Bhowmik and Demissie, 1993). New sediments can promote the growth and establishment of early successional emergent species such as river bulrush (*Scirpus fluviatilis*) (Sampson, 1921; COE, 1980).

CONCLUSIONS

The evidence presented in this paper should not be interpreted to mean that if left alone, the floodplain landscape today would resemble its presettlement state. There are many natural disturbances, such as flooding, sedimentation, erosion, etc., that can bring about drastic changes in floodplain environments. The conversion of prairies to agriculture and the permanent inundation of floodplain habitats are obviously the result of human activities. Although less obvious, it seems reasonable to infer that the trend away from a more diverse forest toward a forest dominated by silver maple is also directly related to human influences. It should further be noted that results presented here may not agree with conditions found in some other areas of the UMR system. This is because the effects of settlement on floodplain ecosystems vary, especially when considering the effects of river impoundments. For example, the degree of forest disturbance due to impoundment is probably greatest just upstream of each impounding dam, where river water levels are most severely raised. Impoundment effects decrease upstream of each dam, and the degree of forest disturbance accordingly decreases upstream of each dam. Because the floodplain area under consideration here is located at mid-reach (Fig. 1), the effects of impoundment on the floodplain forests may be moderate.

Presently, there is much attention on enhancing or restoring the ecological integrity of the UMR system. Habitat rehabilitation and enhancement projects now being conducted by the U.S. Army Corps of Engineers are aimed at combating habitat degradation caused by alterations within the river and its drainage basin. These projects may represent the next generation of river-floodplain modifications. GLO survey records should be used in the planning and implementation of some of these projects because they provide worthwhile data about the natural conditions of the UMR system. Furthermore, GLO survey records can help focus attention on preserving habitats least affected by settlement and on restoring those habitats most severely affected by settlement. In the case of our study area, the mesic prairie and savannah communities have been eliminated and the forests are lacking diversity. If the presence of natural conditions of floodplains and their inherent biodiversity are considered worthwhile, then steps should be taken to reintroduce or promote the establishment of the natural plant communities that existed prior to settlement.

ACKNOWLEDGEMENTS

We thank Dr. Neal Lopinot of the U.S. Army Corps of Engineers, St. Louis District, for his valuable assistance and critical review; Dr. Wayne Temple, Director, Illinois State Archives, for providing and assisting with the GLO survey notes; Sara Rogers, U.S. Fish and Wildlife Service, Environmental Management Technical Center, and Yao Yin, Missouri Department of Conservation for their critical review. We also thank the personnel at the Illinois Natural History Survey's LTRMP Pool 26 field station who assisted in forest sampling during 1992. Funding of this project was provided by the U.S. Fish and Wildlife Service under the Long Term Resource Monitoring Program.

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Fig 1. Map of study area at the confluence of the Illinois and Mississippi rivers and its location within Navigation Pool 26.

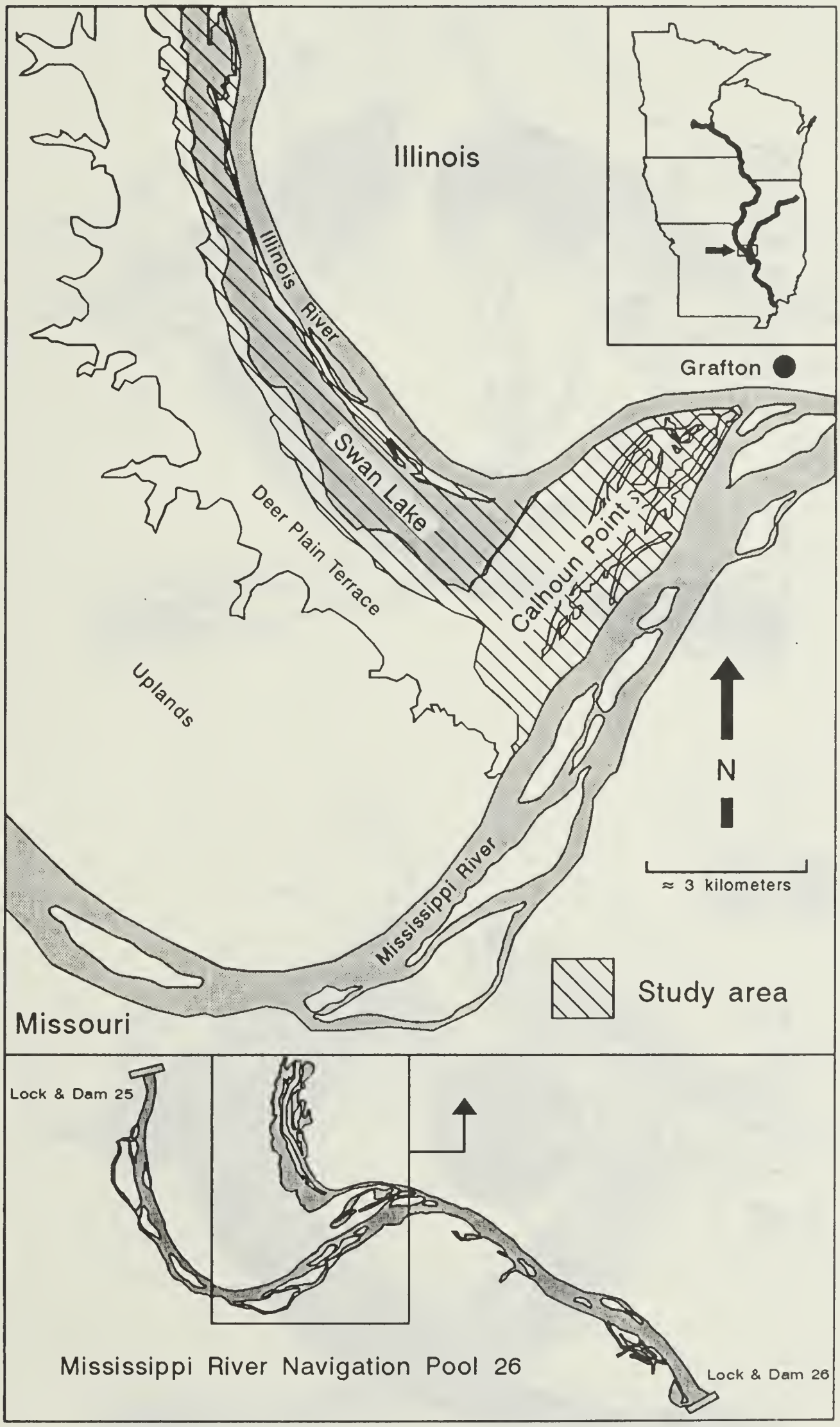
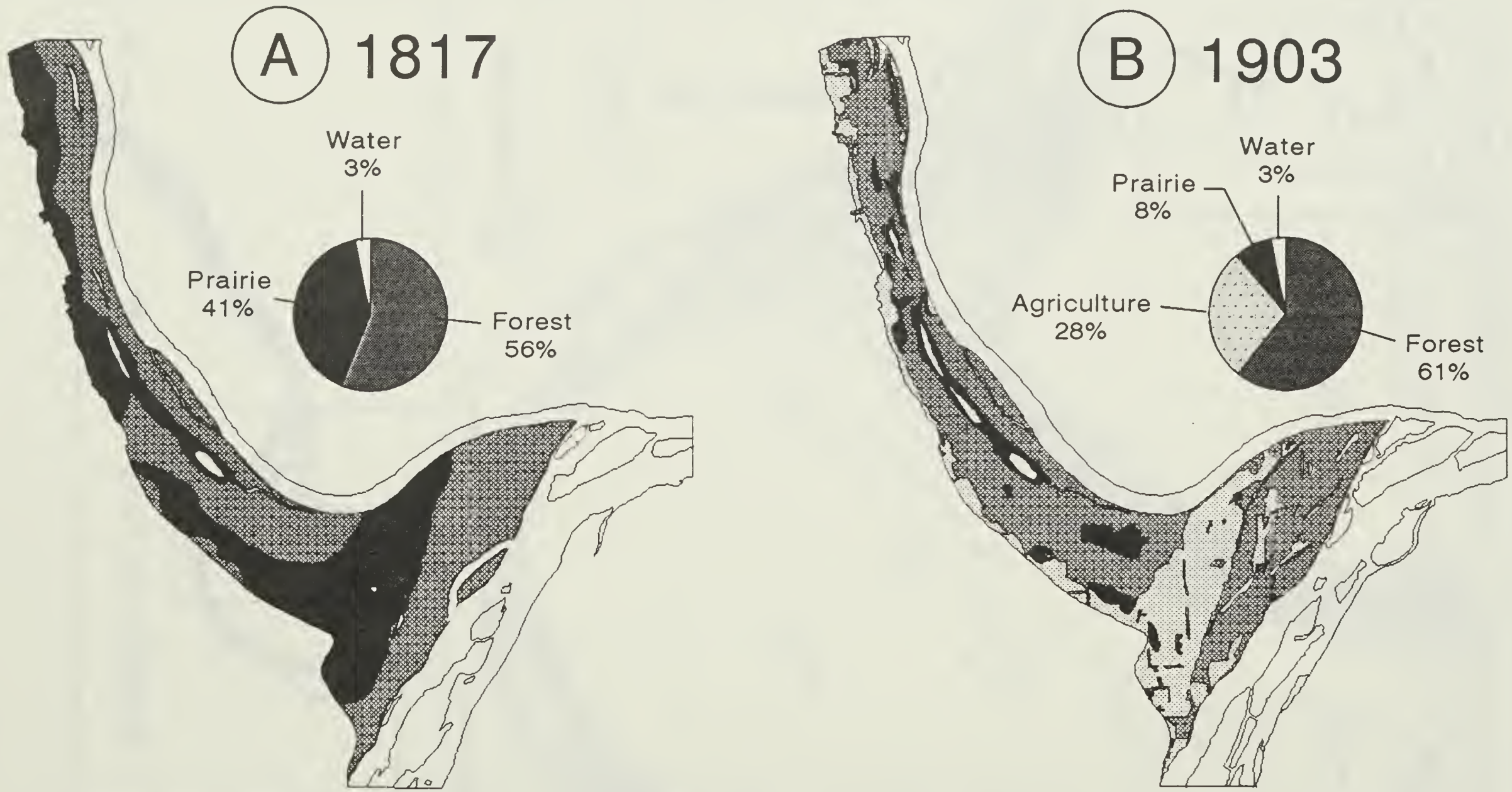
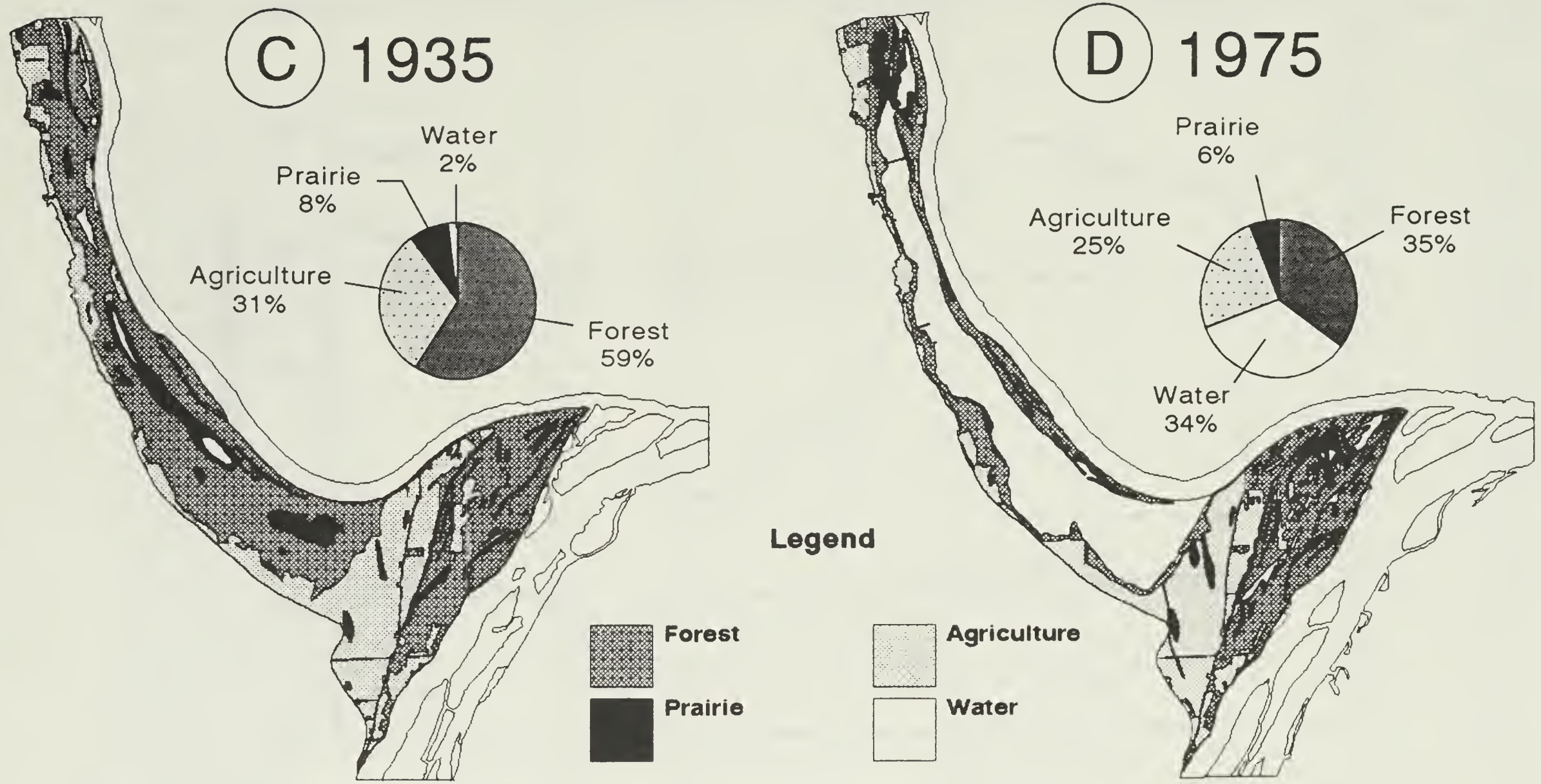


Fig 2. Geographic information system maps showing the percent distribution of several land cover types in 1817, 1903, 1935, and 1975.




C 1935
Water
2%
Prairie
8%
Agriculture
31%
Forest
59%
D 1975
Prairie
6%
Agriculture
25%
Forest
35%
Water
34%
Legend
Forest
Agriculture
Prairie
Water

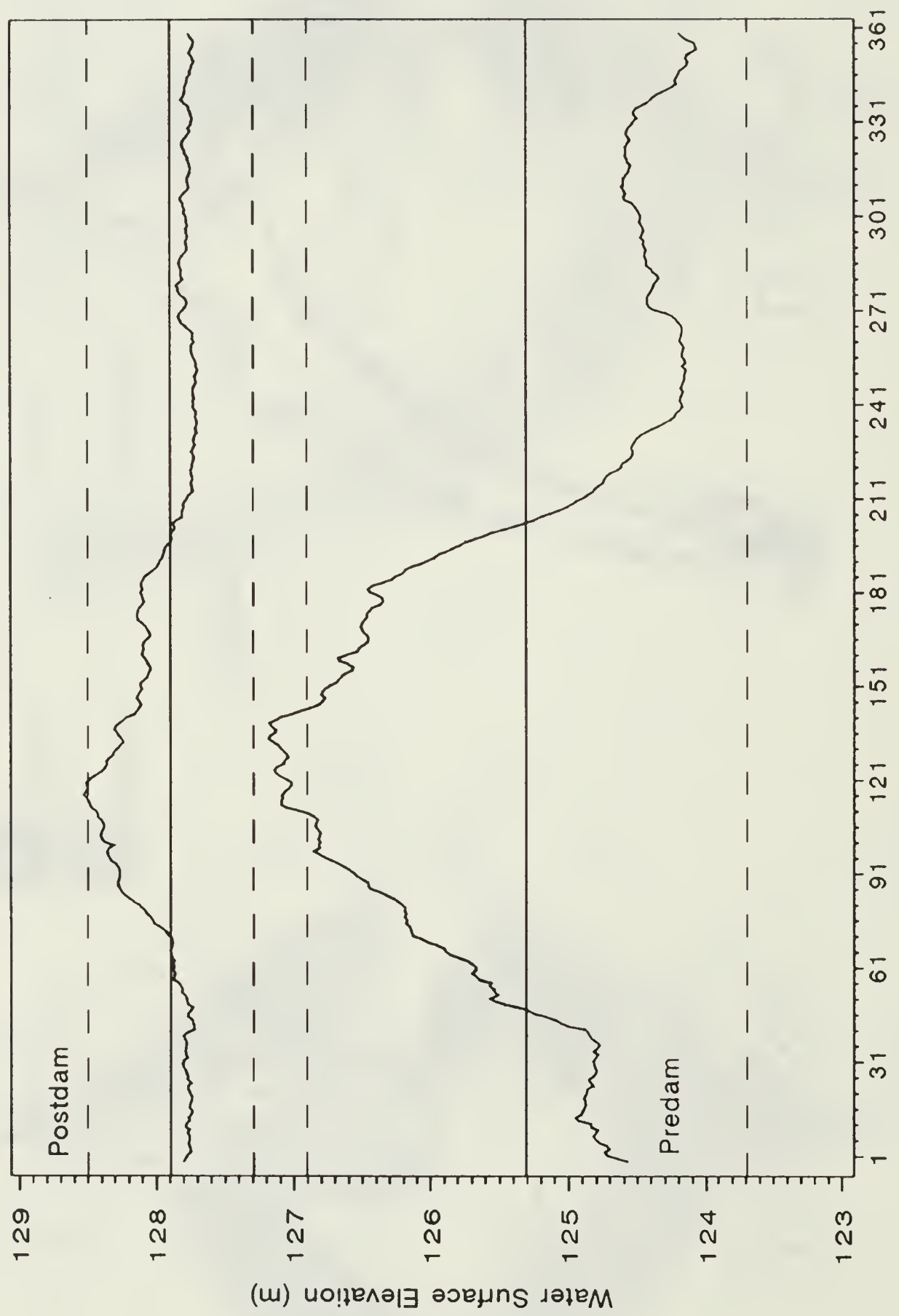


Fig 3. Mean annual hydrographs from predam (n=23 yr) and postdam (n=50 yr) periods at the Grafton, Illinois, gage. Solid horizontal lines indicate overall means; dashed lines directly above and below each indicate ± 1 SD.

Table 1. Presettlement and present floodplain forest composition at the confluence of the Illinois and Mississippi rivers. Mean diameter breast height (dbh), relative density, relative dominance, and importance value (Rel. Dens. + Rel. Dom.) and importance value of all stems 10.0 cm or greater dbh in 1817 and 1992. Species ranked by imporatnce value in 1817.

Genus/species/surveyors common name	Mean dbh(cm)		Rel. Density		Rel. Dominance		Importance Value		
	1817	1992	1817	1992	1817	1992	1817	1992	▲
Celtis occidentalis (Hackberry)	29.6	17.0	17.5	15.0	12.9	4.7	30.4	19.7	- 10.7
Carya illinoensis (Peckon)	49.1	48.9	9.3	2.6	20.7	6.5	30.0	9.1	- 20.9
Ulmus spp. (Elm)	50.1	17.5	9.3	6.6	12.8	2.1	22.1	8.7	- 13.4
Salix spp. (Willow)	24.5	30.5	12.4	6.4	8.3	6.5	20.7	12.9	- 7.8
Populus deltoides (Cottonwood)	30.5	59.9	10.3	2.9	10.1	10.2	20.4	13.1	- 7.3
Acer saccharinum (Maple)	21.8	29.7	10.3	41.4	5.8	44.9	16.1	86.3	+ 70.2
Quercus palustris (Pin oak)	50.8	41.3	3.1	3.2	8.4	6.3	11.5	9.5	- 2.0
Fraxinus spp. (Ash)	36.4	32.9	6.2	8.2	4.8	9.7	11.0	17.9	+ 6.9
Quercus velutina (B. oak)	37.2	----	3.1	----	4.6	----	7.7	----	- 7.7
Acer negundo (Boxelder)	19.7	23.6	4.1	9.1	1.7	5.6	5.8	14.7	+ 8.9
Gleditsia spp. (Locust)	23.7	22.1	3.1	0.2	2.1	0.1	5.2	0.3	- 4.9
Morus spp. (Mulberry)	25.4	13.9	2.1	0.3	1.4	0.1	3.5	0.4	- 3.1
Quercus alba (W. oak)	38.1	----	2.1	----	1.0	----	3.1	----	- 3.1
Cercis canadensis (Redbud)	19.0	----	2.1	----	1.0	----	3.1	----	- 3.1
Platanus occidentalis (Sickimore)	40.6	37.6	1.0	0.6	1.8	1.3	2.8	1.9	- 0.9
Crataegus spp. (Red haw)	30.5	12.9	1.0	1.0	0.8	0.1	1.8	1.1	- 0.7
Quercus macrocarpa (Burr oak)	25.4	49.9	1.0	0.3	0.7	0.8	1.7	1.1	- 0.6
Asimina triloba (Paw paw)	22.9	----	1.0	----	0.5	----	1.5	----	- 1.5
Betula nigra (Birch)	20.3	29.2	1.0	0.3	0.4	0.3	1.4	0.6	- 0.8
Diospyros virginiana	----	18.5	----	1.4	----	0.5	----	1.9	+ 1.9
Maclura pomifera	----	18.8	----	0.3	----	0.1	----	0.4	+ 0.4
Juglans nigra	----	10.5	----	0.2	----	0.0	----	0.2	+ 0.2
Totals			99.0	99.4	98.0	98.5	197.0	198.0	0.0

Sample size: 1817 n = 96 stems, 1992 n = 628 stems. ▲ = change.

Transactions of the Illinois State Academy of Science
(1994), Volume 87, 3 and 4, pp. 135-144

A Survey of the Freshwater Mussels (Bivalvia:Unionidae) of the Green River Basin, Illinois

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ABSTRACT

The freshwater mussel fauna of the Green River and its tributaries in Illinois has not been investigated previously. During the present study 29 mainstem and tributary stations were sampled, resulting in the collection of 19 species of mussels, 13 of which were represented by live individuals. Only one species included on the Illinois threatened/endangered list was collected during the survey.

INTRODUCTION

The Green River originates approximately four miles west of the village of Steward in Lee County, Illinois. It flows generally west-southwest for 91.2 miles and drains an area of 1131 square miles (Healy, 1979) before emptying into the Rock River near Carbon Cliff in Henry County (Figure 1). The Green River occupies the Green River Lowland Section of the Grand Prairie Natural Division of Illinois (Schwegman, 1973).

The Green River basin was characterized in early settlement times by vast areas of marshlands drained by "Inlet Creek", as the Green River was then known (McClain, 1992). Two areas of marsh, Inlet Swamp and Great Winnebago Swamp, encompassed some 30,000 acres each in the upper portions of the drainage in Lee County. Separating the two was an area of limestone ledges (the "Inlet") located near the present-day town of Amboy. This geological feature caused waters from Inlet Creek to spread, "forming a two to three mile wide, shallow wetland whose waters flowed slowly toward the Rock River to the west".

In 1887 a drainage district was formed which, in 1901, completed the excavation of a series of ditches and blasted a channel through the limestone ledges, effecting the drainage of Inlet Swamp. The Great Winnebago Swamp was similarly drained soon thereafter. In recent years, much of the Green River and virtually all of its tributaries have been maintained by local drainage districts, resulting in periodic dredging and the perpetuation of highly disturbed habitat conditions. Currently, much of the Green River basin consists of little more than a network of straightened channels hemmed in by agricultural levees.

This study was undertaken to determine the species of freshwater mussels currently inhabiting the Green River and its tributaries, not only to secure information concerning

the health and distribution of existing mussel populations within the basin, but also to serve as a basis for comparing the Green River with other stream systems in Illinois and the Midwest.

MATERIALS AND METHODS

A total of 29 mainstem and tributary stations were sampled during the summers of 1991-1992 (Table 1; Figure 2). Most of these stations were also sampled during the Illinois Department of Conservation's Green River fisheries survey (Day et al., 1992). Additional stations were established on tributaries such as Mud Creek and Main Union Special Ditch to insure thorough coverage of the basin.

Mussels were collected by hand picking for four collector-hours at each station, and all available habitats (e.g. riffles, pools, areas of differing substrate, etc.) were searched. Typically, the mussels were identified to the species level in the field, their numbers recorded, and one or two voucher specimens of each species retained for deposition in the mollusk collection of the Illinois Natural History Survey, Champaign, Illinois. If identifications could not be made in the field, the specimens in question were retained for positive identification in the laboratory. Any remaining mussels were returned to the stream.

A photographic record was made of each station and the mussels collected there. Estimates were also made of stream width, average depth, and average rate of flow, and a site map sketched for future reference. Finally, the mussels to be retained as vouchers were bagged and labeled by site number and/or location.

Nomenclature in this report follows that of the Committee on Scientific and Vernacular Names of Mollusks of the Council of Systematic Malacologists, American Malacological Union (Turgeon et al., 1988), except that subspecies are not recognized.

RESULTS AND DISCUSSION

There has been little historical effort to investigate and document the freshwater mussel fauna of the Green River basin. Visits to the major malacological collections in the United States revealed only three specimens from the Green River - one *Actinonaias ligamentina*, one *Lampsilis cardium* and one *Lasmigona complanata* - all collected by Clayton Hoff of Quincy (Illinois) College in October, 1934 (K.S. Cummings, INHS, pers. comm.). These specimens currently reside in the collections of the Illinois State Museum.

During the current study, nineteen species of freshwater mussels were collected, of which thirteen species were represented by living specimens totalling 163 individuals (Table 2). One hundred sixteen collector-hours were spent in sampling, with an average of less than two mussels collected per hour.

The most common species collected live were *Lasmigona complanata* and *Anodonta grandis*, which constituted 25.15% and 20.25%, respectively, of the total sample (Table 2). Two additional species represented fifteen percent or more of the live sample:

Strophitus undulatus at 17.18% and *Lampsilis cardium* at 15.95%. Six species were represented by only one live individual each and included *Anodonta imbecillis*, *Lasmigona compressa*, *Potamilus ohiensis*, *Quadrula pustulosa*, *Toxolasma parvus* and *Tritogonia verrucosa*.

The number of live specimens collected at a given station ranged from 0 to 28, with an average of approximately 6, and the number of species represented by live and/or dead material ranged from 0 to 9, with an average of less than 3 (Table 3). Station 20 on Coal Creek in Bureau County had the greatest species richness, with 9 species. Station 13 on Walnut Special Ditch in Bureau County supported the highest abundance, yielding 28 live individuals (23 of which were *Lasmigona complanata*).

The Green River mainstem produced 14 of the 19 total species collected. Species that were not found in the Green River proper, but only in its tributaries, included *Elliptio dilatata*, *Lampsilis siliquoidea*, *Quadrula nodulata*, *Quadrula pustulosa* and *Tritogonia verrucosa*. Only one species included on the Illinois endangered and threatened species list (Herkert, 1992) was collected during the present study: a single *Lasmigona compressa*, currently listed as threatened, taken at station 3 on the Green River mainstem.

The relative paucity of freshwater mussels in the Green River basin is most likely a result of its agricultural history. As was noted earlier, much of the basin consists of channels that were artificially created for drainage purposes or, in the case of pre-settlement drainageways, have since been straightened, deepened and maintained by local drainage districts. Day et al. (1992) found the Green River to hold "diverse sport fishing opportunities" which were attributed to its high base flow, cool water temperatures, and favorable dissolved oxygen levels. The absence of significant instream structure and floodplain habitat caused by agricultural practices in the basin were considered limiting to its fish production.

No doubt the same practices that limit the availability of instream structure (e.g. dredging, channelization) are similarly limiting to the recruitment and survival of freshwater mussel populations. The high incidence of loose sand substrates on the Green River mainstem downstream from Station 4 and on many of the tributaries (e.g. Willow Creek, Winnebago Ditch) is also undoubtedly a negative factor affecting mussel populations (Parmalee, 1967).

The Illinois Department of Conservation's investigations in the Green River basin (Day et al., 1992) were primarily aimed at evaluating the basin's fishery and, based on a variety of factors including species richness, abundance, disease, etc., rating the stations sampled using Karr's Index of Biotic Integrity or IBI (Karr, 1981; Karr et al., 1986). Stations within the basin received IBI ratings ranging from "Limited Aquatic Resource" to "Highly Valued Aquatic Resource". Interestingly, the IBI data do not appear to correlate well with the mussel collection results.

Although some stations that ranked highly based on the fisheries data also supported relatively diverse and abundant mussel populations (e.g. Stations 2 and 3), others hosted few or no live mussels (e.g. Stations 1 and 4). Station 20, which had the greatest mussel species richness, received an IBI score of only 28 (Limited Aquatic Resource) based on the

fisheries data. One may conclude that some factor or factors particularly limiting to sedentary organisms - perhaps substrate type or frequency of artificial disturbance - has caused these discrepancies, since parameters such as high base flow, cool water temperatures and high dissolved oxygen could be expected to benefit both fish and mussels.

ACKNOWLEDGMENTS

We wish to thank Ed Anderson, David Day, Dan Holm, Jean Karnes, Randy Nÿboer and Randy Sauer of the Illinois Department of Conservation for assisting with sampling activities. David Day also contributed several mussel specimens collected during the Green River fisheries survey. Kevin Cummings of the Illinois Natural History Survey provided information concerning Green River mussels housed in other institutional collections and also, with assistance from Christine Mayer, curated the specimens collected during the study. He is also thanked, as is Dr. Richard Sparks, for reviewing the manuscript and providing many helpful comments.

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Figure 1. The Green River and its major tributaries.

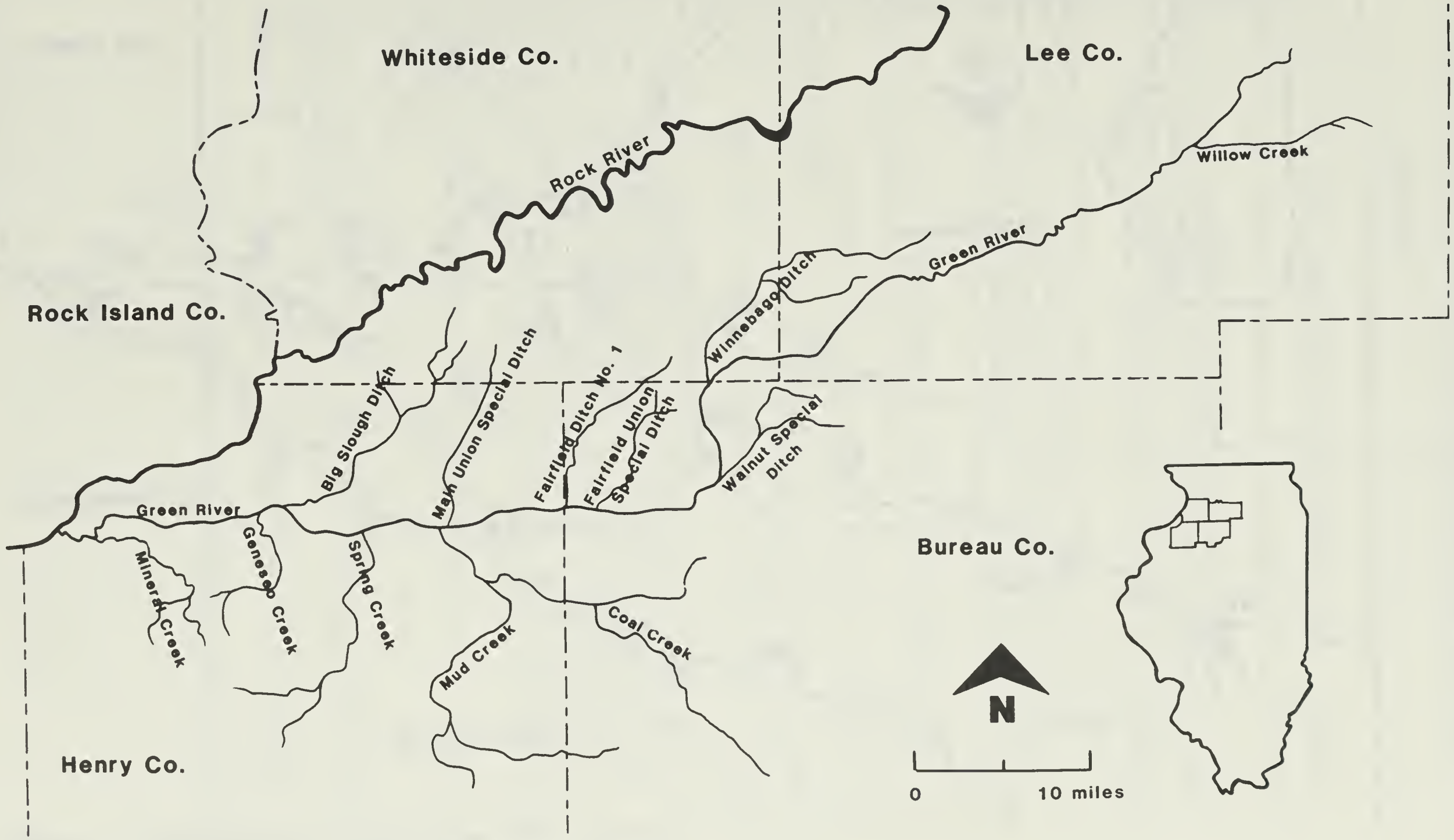

Figure 2. Collection sites in the Green River basin, 1991-1992.

Table 1. Collection sites in the Green River basin, and date of sampling, 1991-1992.

SITE #	LOCATION
1.	Green River, County Road 2400E bridge, Lee Co. T38N, R1E, sec. 7. September 16, 1991.
2.	Green River, Route 52 bridge at Amboy, Lee Co. T20N, R10E, sec. 22. September 16, 1991.
3.	Green River, Walton Road bridge, Lee Co. T20N, R9E, sec. 34. September 16, 1991.
4.	Green River, Harmon Road bridge, Lee Co. T19N, R8E, sec. 15. September 17, 1991.
5.	Green River, Route 88 bridge, Whiteside Co. T19N, R7E, sec. 33. May 18, 1992.
6.	Green River, 6 mi. WSW New Bedford, Bureau Co. T17N, R6E, sec. 5. September 18, 1991.
7.	Green River, 4.5 mi. NW Atkinson, Henry Co. T17N, R4E, sec. 8. May 19, 1992.
8.	Green River, Route 82 bridge, Henry Co. T17N, R3E, sec. 4. May 19, 1992.
9.	Green River, N-S bridge at Colona, Henry Co. T17N, R1E, sec. 12. May 20, 1992.
10.	Willow Creek, County Road 2400E bridge, Lee Co. T38N, R1E, sec. 18. June 10, 1991.
11.	Winnebago Ditch, 1.5 mi. N Deer Grove, Whiteside Co. T19N, R7E, sec. 15. June 11, 1991.
12.	Walnut Creek, 1.5 mi. W Walnut, Bureau Co. T18N, R8E, sec. 7. June 11, 1991.
13.	Walnut Special Ditch, 2 mi. ENE New Bedford, Bureau Co. T18N, R7E, sec. 27. June 11, 1991.
14.	Fairfield Union Special Ditch, 5 mi. W New Bedford, Bureau Co. T18N, R6E, sec. 33. September 17, 1991.
15.	Fairfield Ditch No. 1, 3 mi. ESE Hoopole, Bureau Co. T18N, R6E, sec. 31. September 17, 1991.
16.	Main Union Special Ditch, Route 92 bridge, Henry Co. T18N, R5E, sec. 18. May 21, 1992.
17.	Coal Creek, 1.25 mi. S Sheffield, Bureau Co. T16N, R7E, sec. 30. June 12, 1991.
18.	Coal Creek, 2.5 mi. E Mineral, Bureau Co. T16N, R6E, sec. 10. June 12, 1991.
19.	Coal Creek, 2.5 mi. NNW Mineral, Bureau Co. T17N, R6E, sec. 31. June 12, 1991.
20.	Coal Creek, 2 mi. NNW Annawan, Henry Co. T17N, R5E, sec. 28. June 13, 1991.
21.	Mud Creek, 4 mi. NNE Kewanee, Henry Co. T15N, R5E, sec. 7. October 6, 1992.
22.	Mud Creek, 2 mi. NW Annawan, Henry Co. T17N, R5E, sec. 33. October 6, 1992.
23.	Mud Creek, 3.5 mi. NE Atkinson, Henry Co. T17N, R5E, sec. 18. June 13, 1991.
24.	Spring Creek, 2.5 mi. WNW Atkinson, Henry Co. T17N, R4E, sec. 30. June 13, 1991 & July 25, 1991.
25.	Spring Creek, 3 mi. NW Atkinson, Henry Co. T17N, R4E, sec. 17. September 18, 1991.
26.	Big Slough Ditch, 5 mi. NE Geneseo, Henry Co. T18N, R3E, sec. 36. September 18, 1991.
27.	Big Slough Ditch, 3 mi. NNE Geneseo, Henry Co. T17N, R3E, sec. 3. May 19, 1992.
28.	Geneseo Creek, Route 6 bridge in Geneseo, Henry Co. T17N, R3E, sec. 21. May 20, 1992.
29.	Mineral Creek, 2 mi. SE Colona, Henry Co. T17N, R2E, sec. 20. May 20, 1992.

Table 2. Total numbers, abundance ranking and percent composition of the mussel species collected in the Green River basin, 1991-1992.

Species	Total	Rank	%Comp.	Cum.%
Lasmigona complanata	41	1	25.15	25.15
Anodonta grandis	33	2	20.25	45.40
Strophitus undulatus	28	3	17.18	62.58
Lampsilis cardium	26	4	15.95	78.53
Quadrula nodulata	13	5	7.98	86.51
Quadrula quadrula	9	6	5.52	92.03
Anodontoides ferussacianus	7	7	4.29	96.32
Anodonta imbecillis	1	8	.61	96.93
Lasmigona compressa	1	8	.61	97.54
Potamilus ohiensis	1	8	.61	98.15
Quadrula pustulosa	1	8	.61	98.76
Toxolasma parvus	1	8	.61	99.37
Tritogonia verrucosa	1	8	.61	99.98
Actinonaias ligamentina	0			
Amblema plicata	0			
Elliptio dilatata	0			
Lampsilis siliquoidea	0			
Lampsilis teres	0			
Potamilus alatus	0			
Total Live Individuals	163			
Total Species (live)	13			
Total Species	19			

Table 3. Station by station listing of all mussels collected in the Green River basin, 1991-1992.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Actinonaias ligamentina									w						
Amblema plicata		w	w					w							
Anodonta grandis		1	4	w									4		
Anodonta imbecillis						1									
Anodontoides ferussacianus		2	1							1					
Elliptio dilatata															
Lampsilis cardium		5	8	d	7	1			3						
Lampsilis siliquoidea													d		
Lampsilis teres							w								
Lasmigona complanata		1	3			d					1		23		
Lasmigona compressa			1												
Potamilus alatus									d						
Potamilus ohiensis						d			1						
Quadrula nodulata															
Quadrula pustulosa															
Quadrula quadrula						d									
Strophitus undulatus	1	w											1	w	
Toxolasma parvus						w									
Tritogonia verrucosa															
TOTAL LIVE INDIVIDUALS	1	9	17	0	7	2	0	0	4	1	1	0	28	0	0
NO. SPECIES (LIVE)	1	4	5	0	1	2	0	0	2	1	1	0	3	0	0
NO. SPECIES (DEAD)	0	2	1	2	0	4	1	1	2	0	0	0	1	1	0
TOTAL SPECIES	1	6	6	2	1	6	1	1	4	1	1	0	4	1	0

d = dead (nacre shiny, periostracum mostly intact)
w = weathered (nacre dull, periostracum partly to mostly gone)

Table 3. (continued)

	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Actinonaias ligamentina														
Amblema plicata					w									
Anodonta grandis									8	d	10	5		1
Anodonta imbecillis				w							d			
Anodontoides ferussacianus		d	d	1	w		1					1		
Elliptio dilatata										w				
Lampsilis cardium				1	1									
Lampsilis siliquoidea					w									
Lampsilis teres														
Lasmigona complanata					4		1		2	d	2	4		
Lasmigona compressa														
Potamilus alatus														
Potamilus ohiensis														
Quadrula nodulata				3	9		1							
Quadrula pustulosa					1									
Quadrula quadrula				1	6		2							
Strophitus undulatus		d	1	3			4	w	2	d	1	15		
Toxolasma parvus							1							
Tritogonia verrucosa					1									
TOTAL LIVE INDIVIDUALS	0	0	1	9	22	0	10	0	12	0	13	25	0	1
NO. SPECIES (LIVE)	0	0	1	5	6	0	6	0	3	0	3	4	0	1
NO. SPECIES (DEAD)	0	2	1	1	3	0	0	1	0	4	1	0	0	0
TOTAL SPECIES	0	2	2	6	9	0	6	1	3	4	4	4	0	1

Transactions of the Illinois State Academy of Science
(1994), Volume 87, 3 and 4, pp. 145-150

Individual and Relative Fecundity of Black Crappie (*Pomoxis nigromaculatus*) in Baldwin Cooling Pond

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ABSTRACT

Individual and relative fecundity were determined for eleven black crappie (*Pomoxis nigromaculatus*) collected in 1987 from Baldwin Cooling Pond, Randolph County, Illinois. Estimated number of mature ova ranged from 33,940 to 348,400 ova per individual in fish 225-322 mm in length. Mean value for individual fecundity was 143,762 ova per individual with mean relative fecundity of 411 ova per gram or 5000 ova per centimeter of total length. Individual fecundity was strongly correlated to both length and weight. Low recruitment was probably due to strong winds and to extreme and rapidly fluctuating water temperatures rather than fecundity.

INTRODUCTION

Crappie are an extremely popular sport fish in the United States, and were ranked first by Illinois anglers in terms of fishing preference (Baur 1988). As a result, management agencies spend considerable effort in the management of crappie populations. Often, crappie populations are characterized by slow growth and high recruitment which results in populations composed of small stunted fish (Ellison 1984).

In Illinois, electrical power generating cooling impoundments such as Baldwin, Heidecke, Powerton, La Salle, etc., provide a significant angling resource. However, in many of these impoundments, black crappie populations are often characterized by consistently low recruitment to the breeding population and by fast growth. Although condition of individuals is excellent, density is often too low to sustain an acceptable fishery.

In analyzing problems with recruitment, fecundity of broodstock is one parameter that should be considered (Cushing 1971; Schwartzman et al. 1977). We found only one published study that determined fecundity of either black or white crappie (*P. annularis*) in a power cooling impoundment. Barwick (1981) evaluated fecundity of 59 female black

crappie in Keowee Reservoir, South Carolina, a 7,435 ha reservoir operating under the influence of a 2580 MW nuclear electrical generating facility. Baldwin Lake is typical of many power cooling impoundments in that both white and black crappie exhibit problems with recruitment to the breeding population and with maintaining strong populations. Consistently low population densities and poor angler success at Baldwin Lake led to the investigation of fecundity as a potential factor for poor recruitment in this impoundment.

MATERIALS AND METHODS

Baldwin Cooling Pond is a 796-ha body of water, located in Randolph County, Illinois, with a mean depth of 3 meters and a maximum depth of 15.2 meters. The pond is rectangular with 90 percent of the 23.4 kilometer shoreline composed of rip-rapped levees. It provides cooling water for three base loaded 600-megawatt coal fired generating units.

Black crappie were collected in 1987-1988 for age and growth analysis. Black crappie were collected for fecundity analysis by weekly spring trapnetting from March 19 to May 7 in 1987. Water temperatures throughout the sampling period ranged from 15-30°C. Large trap nets were used, similar to those described by Willis et al. (1984). These trap nets consisted of a 122 cm x 178 cm frame, 1.2 cm bar mesh, and a 6 or 15.2 m lead. These nets were set throughout the pond but more often in suspected spring spawning areas. Individuals selected for fecundity analysis were classified as being in the ripening phase of gonad maturation (Snyder 1983). Ovaries were preserved in Gilson's fluid for approximately five months to allow the preservative to break down connective tissue and free the eggs from ovarian tissue. Samples were frequently agitated during the holding period to facilitate their separation. Enumeration of eggs was conducted in a manner similar to that described by Bagenal (1968) and Snyder (1983). Each sample was processed by carefully removing all remaining ovarian tissue from the eggs. All eggs were then washed repeatedly in tap water. When washings were clear of ovarian tissue, the eggs were placed in a graduated cylinder. To facilitate mixing of eggs for random sampling, a known volume of water was added. A large bore pipette was used to remove a subsample of known volume of eggs immediately after thorough mixing of the whole egg mass. Three subsamples were obtained and eggs were counted using a binocular dissecting microscope.

One-hundred eggs were randomly selected from one subsample and measured with an ocular micrometer to determine the percentage of maturing eggs in each sample. Black crappie spawn annually, in the spring or early summer; however, Barwick (1981) noted that not all ova in black crappie ovaries reach maturity each year. He observed smaller ova which remained in the ovaries in fish that were spent but considered only ova equal to or greater than 0.306 mm in diameter as being capable of reaching maturity. In order to help standardize the method of estimating fecundity, only ova equal to or larger than 0.306 mm were counted in this study. The mean egg counts from the three subsamples were converted to the total number of eggs present in the sample (individual fecundity). Individual fecundity was divided by the weight of the fish to give the value for relative fecundity in number of eggs/gram and by total length of the fish to determine relative fecundity in number of eggs/cm.

RESULTS

In 1987-1987, 231 net nights of trapnetting yielded 139 black crappie for a mean catch per unit effort of only 0.6 fish per net night. Although numbers of fish were low, growth was excellent. Black crappie reached a harvestable total length limit of 229 mm between their second and third years of life. The mean total length for 36 United States central water populations by age three was 188 mm (Carlander 1977). The mean relative weight (Wr) value for all black crappie collected from Baldwin Lake was 97% of the standard length weight curve (Murphy et al. 1991).

Black crappie collected in the spring of 1987 were used in analysis of fecundity. Eleven female and seventeen males were collected in March-May 1987 in 56 net nights, resulting in a catch per unit effort of 0.5 fish per night. The estimated number of mature ova from the 225-332 mm crappie ranged from 33,940 to 348,400 ova per female. The mean value for individual fecundity was 143,762 (SD± 108,544) ova per female. Weight related relative fecundity estimates ranged from 157-643 ova per gram with a mean of 411 ova per gram (SD± 171). Total length related relative fecundity ranted from 1,383-11,025 ova per centimeter with a mean of 5,110 ova per centimeter (SD± 3077).

In Baldwin Cooling Pond, individual fecundity was significantly and almost equally correlated with both length and weight. The fecundity - weight relation from least squares regression analysis was best expressed by the following equation (Fig. 1):

$$\log \text{fecundity} = 1.4327 + 1.4643 \log \text{weight with a calculated } r^2 \text{ value of } 0.7558$$

The fecundity - length relation also showed a strong correlation, and was best expressed by the following equation (Fig. 2):

$$\log \text{fecundity} = -6.2192 + 4.6580 \log \text{length with a calculated } r^2 \text{ value of } 0.7449$$

DISCUSSION

Regardless of predictive capabilities, fecundity of black crappie collected in 1987 were clearly very high. Carlander (1977) lists eight studies (six in gray literature) in which individual fecundity of black crappie was determined. Values ranged from 11,000 to 188,000 ova per female for 73 to 680 g fish. Relative fecundity values were not given.

Occurrence of extremely high fecundity may be due to several factors. Studies by Scott (1961) on rainbow trout (*Oncorhynchus mykiss*) have documented that insufficient diet caused a reduction in egg number due to follicular atresia. Hester (1963) found that female guppies (*Lebistes reticulatus*) produced fewer offspring when adults were fed an insufficient diet. As previously discussed, the black crappie in Baldwin Cooling Pond exhibit excellent condition and growth. Conceivably, the abundance of food in the form of threadfin shad (*Dorosoma petenense*) and low density of adults may explain the high fecundity observed in Baldwin Cooling Pond.

Bagenal (1978) discusses the hypothesis that fecundity can be a population regulator, resulting in more ova being produced to cope with adverse environmental conditions. Baldwin Cooling Pond is subjected to strong winds and rapid fluctuations and extremes of

temperature. Due to the open, almost treeless topography surrounding the lake, even low velocity winds can result in extreme wave action. Water temperatures fluctuate widely depending on intensity of power generation, and in 1987 ranged from 13°C on March 12 to 35°C on June 24. Summer temperatures are occasionally recorded which exceed 40°C when warm water from the power plant is discharged into the lake. Even though fecundity is relatively high it apparently has not offset other factors which negatively impact development of a strong sport fishery for this species in Baldwin Cooling Pond.

ACKNOWLEDGMENTS

This research was part of Illinois Federal Aid in Sport Fish Restoration, Project F-73-R-1.

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Figure 1. Individual fecundity of black crappie in Baldwin Cooling Pond as a Function of total weight.

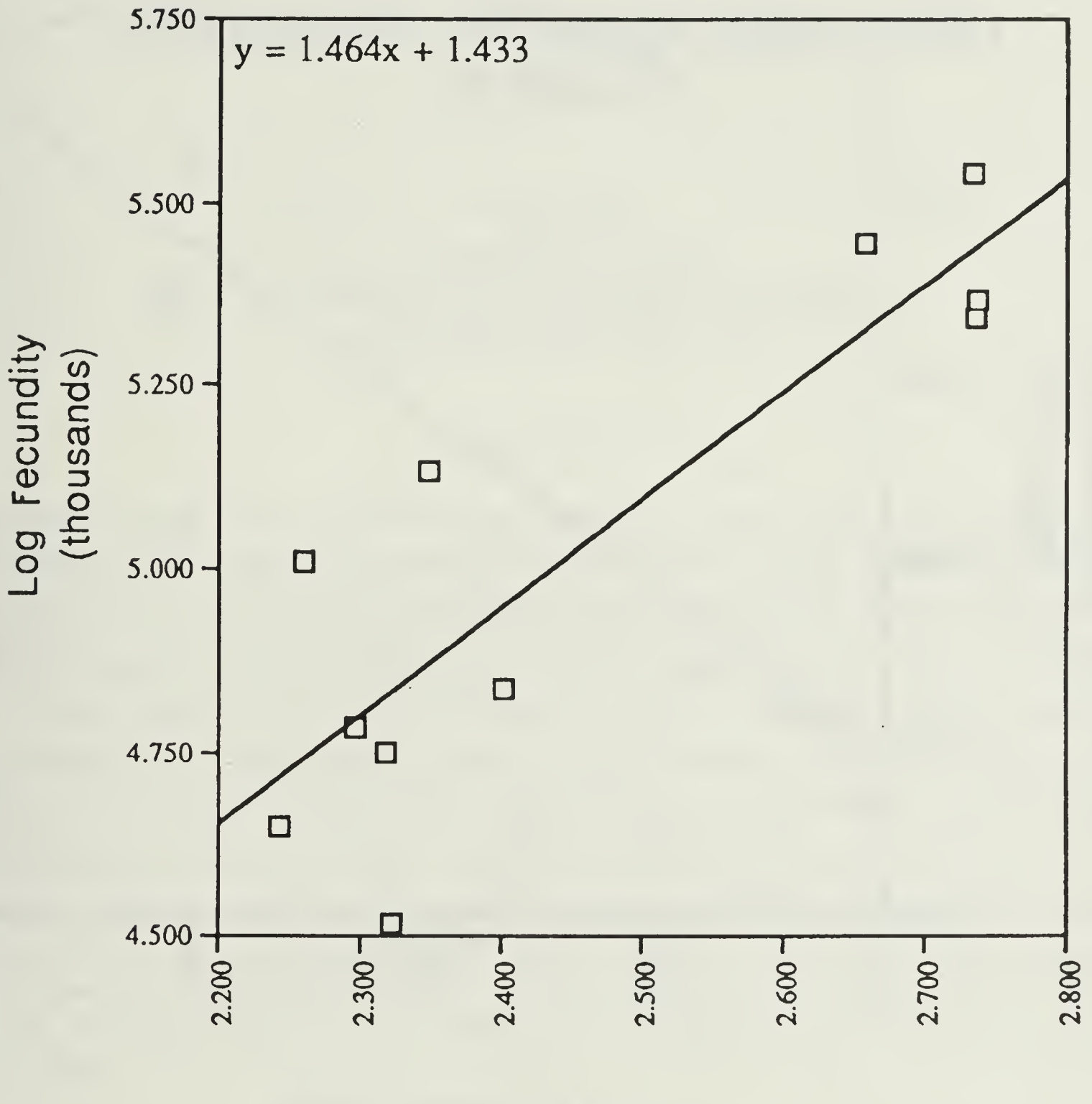
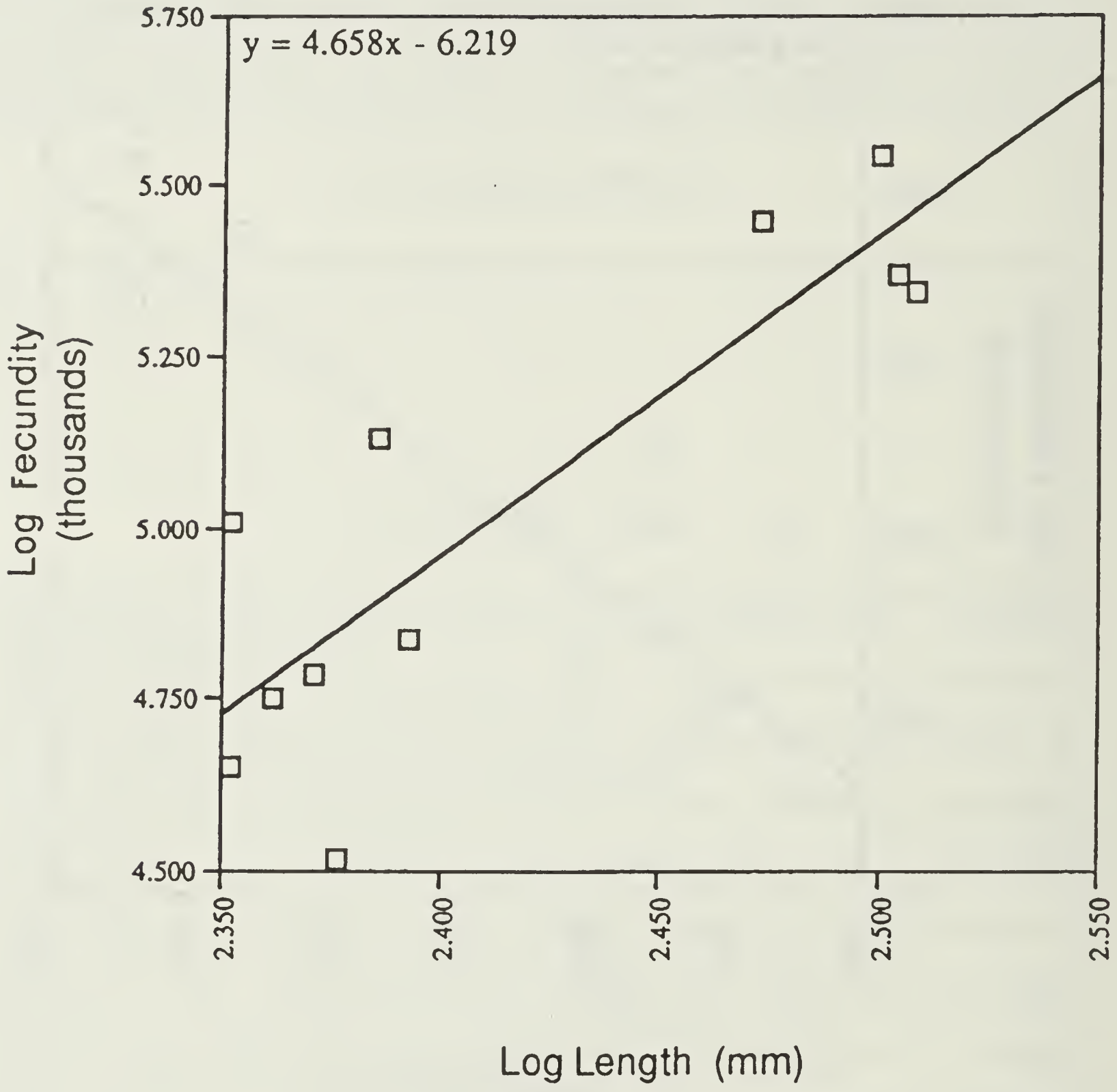


Figure 2. Individual fecundity of black crappie in Baldwin Cooling Pond as a Function of total length.



Transactions of the Illinois State Academy of Science
(1994), Volume 87, 3 and 4, pp. 151-163

Geographic Variation, Status, and Distribution of Kirtland's Snake (*Clonophis kirtlandii* Kennicott) in Illinois

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ABSTRACT

Kirtland's snake, *Clonophis kirtlandii* (Kennicott, 1856), shows slight geographic variation in head scutellation and dorsal blotch number in Illinois. Although significant differences in mean number of supralabials, postoculars, anterior temporals, and lateral blotches exist between northern and southern populations, results of Principal Components Analysis does not suggest more than a single taxon in Illinois. Original wet prairie habitat of *C. kirtlandii* is virtually nonexistent in Illinois and most remaining populations are isolated remnants in greatly disturbed habitats A survey was conducted at 33 sites, 27 of them in southern and western Illinois and the remainder in northeastern Illinois. One new population was found in Fulton County. Of the 70 localities represented by literature reports, museum specimens, and anecdotal reports, there is evidence that only eight currently support reproducing populations. Requirements include crayfish burrows in open areas that are prone to seasonal flooding. Intensive, long-term surveys are recommended to determine whether any additional populations of *C. kirtlandii* exist. Pending results of further investigation, *C. kirtlandii* should be listed as threatened in Illinois.

INTRODUCTION

Kirtland's snake, *Clonophis kirtlandii*, is a poorly known, fossorial colubrid endemic to the midwestern USA. It was described as *Regina kirtlandii*, by Kennicott (1856), from specimens collected in West Northfield, Cook County, Illinois. Detailed morphological descriptions appear in Conant (1938, 1943), Rossman and Powell (1985), and Ernst and Barbour (1989).

Information on the life history of *C. kirtlandii* is scant. Reported food items are mainly soft-bodied invertebrates such as earthworms, slugs, and leeches (Atkinson, 1901; Conant, 1938; Minton, 1944; Tucker, 1977) but recently water striders (Thurow, 1993), and crayfish (Bavetz, 1993) have been documented.

The original habitat of *C. kirtlandii* consisted of wet prairies, wet meadows, prairie fens, and associated wetlands, (Conant, 1943) most of which have long since been drained and

converted to agriculture (Reichenbach and Dalrymple, 1981). Present habitat consists mainly of open low grassy areas at the margins of either creeks, ponds or ditches (Minton, 1972; Ernst and Barbour, 1989; this study). Populations at the periphery of the range occur in relatively open woods while those in the core are more commonly found in urban or floodplain habitats (Wilsmann and Sellers, 1988; Conant, 1943; Minton, 1972).

At present, *C. kirtlandii* is listed as endangered in Kentucky (Warren et al., 1986) and Michigan (Holman et al., 1989), and as "status undetermined" in Pennsylvania (Genoways and Brenner, 1985). It presently may be appropriate for federal listing as endangered or threatened but more information is needed to determine its status and vulnerability (category 2 species, U. S. Fish and Wildlife Service, Dodd et al., 1985). Most known populations persist in either urban or other disturbed habitats and consequently are vulnerable to extirpation (Conant, 1938; McCoy, 1982). Many of these populations have been either declining or are extirpated (Garman, 1892; Minton et al., 1983; Wilsmann and Sellers, 1988).

After Kennicott's original description in 1856, *Clonophis kirtlandii* was subsequently found in Champaign-Urbana and Bloomington-Normal in the late 1800's. Specimens were presented to the British Museum in 1893 (C. McCarthey pers. comm.) by professor S. A. Forbes (Boulenger, 1896). By 1945, *C. kirtlandii* was known from several additional areas in or near Chicago and from Coles, DuPage, and Piatt counties (Hankinson, 1917; Schmidt and Necker, 1935, Pope, 1944).

Smith (1961) provided a map with all documented localities and several new ones that were discovered in the years 1948-57. Many populations have been reported or documented since Smith's work and the range has been extended considerably to the west and south (Brown, 1987; Brown et al., 1975; Clark, 1961; Moll, 1962; Holman and Arai, 1962; Morris, 1975; Munyer and Parmalee, 1967; Papiernik and Dundek, 1988; Tucker et al., 1977; Webb, 1985).

The objectives of this study were: (1) to attempt to determine the present status and distribution of *C. kirtlandii* in Illinois by searching for populations in the field, contacting individuals who have knowledge of extant populations or have observed snakes in the field, and compiling a bibliography and list of museum specimens; (2) to examine and describe the habitat of extant Illinois populations; and (3) determine if geographic variation exists in Illinois by collecting and analyzing morphological data.

MATERIALS AND METHODS

Specific localities were determined from the literature, museum specimens, Illinois Department of Conservation (IDOC) records, and from several people who sent photographs or reported seeing *C. kirtlandii* in Illinois.

Sites were classified according to their reliability. "Confirmed" sites are based on photographic slides or voucher specimens. Unconfirmed sites were classified as either "reported" or "anecdotal." Reported sites included those mentioned in the literature but for which no voucher specimen exists. Anecdotal sites are documented by neither voucher

specimens nor publications but were reported to me or to the IDOC by various individuals.

Restrictions on time, logistics, and funding made a limited survey on the lesser known localities in southern and western Illinois more feasible than a statewide survey. Most central and northern Illinois sites are well monitored by the IDOC. Between June 1991 and May, 1993, 33 locations were surveyed. Nineteen were confirmed or unconfirmed sites. The remainder were in the vicinity of a site and contained habitat that appeared suitable. Suitable habitat was taken to be pond, lake, and creek margins in the immediate vicinity of open areas or mowed grass. All of the sites examined appeared prone to immersion from seasonal flooding and contained active crayfish burrows (chimneys present). The searches were conducted by turning over cover and debris, especially along the water's edge, and inspecting the ground near crayfish burrows.

Specimens Examined

An effort was made to locate all Illinois specimens. Data were recorded from two live specimens and from 82 museum specimens from the following institutions: British Museum (Natural History) Department of Zoology (BMNH), Chicago Academy of Sciences (CA), Field Museum of Natural History (FMNH), Illinois Natural History Survey (INHS), Harvard University Museum of Comparative Zoology (MCZ), Illinois State Museum(ISM), Illinois State University (ISU), Louisiana State University Museum of Zoology (LSUMZ), National Museum of Natural History (USNM), Southern Illinois University (Carbondale) University Museum (SIUC), University of Illinois Museum of Natural History (UIMNH), University of Michigan Museum of Zoology (UMMZ), The following Illinois sites are confirmed by the associated specimens: Adams County: 1.5 miles [1.9 km] N Quincy (UIMNH 51001); Champaign County: Urbana (INHS 1361, 1363, 1364, ISM 621782); Champaign (INHS 1362); 2.0 miles [3.2 km] S Fisher (INHS 7830); 2 miles [3.2 km] W Seymour (UIMNH 52104) Christian County: Lake Sangchris East Boat Dock (ISM 691223); Coles County: Charleston (INHS 1930, 1931, 2048, 6426); Cook County: West Northfield (UMMZ 43928); Gross Point, Evanston (FMNH 2989, 16126); Chicago Ridge (FMNH 2975, 16127, UMMZ 58609); River Forest near Trailside Museum. (FMNH 25436-25437); 103rd and Central, Chicago Ridge (FMNH 17610); 103rd and Western (CAS 1342); Palos Park (FMNH 23166); Chicago, West Side (CAS 3862); School and Odell (FMNH 154908, 154909); Outside Willow Springs (FMNH 154910) Chicago (CA 16906); 1 mile [1.6 km] S Willow Springs (CA 13713); Oak Lawn (FMNH 83037) Saganashkee Slough (ISM 622042); Carlé Woods (INHS 10748); Orland Park (SIUC R-2367); DeWitt County: 3 miles [4.8 km] E Clinton (INHS 9087); Douglas County: Chesterville (INHS 2049, 2754); Villa Grove (INHS 8139, 10231, 10261); DuPage County: Westmont (FMNH 38063); Effingham County: Henrietta Street and Fayette Avenue, Effingham. (INHS 3544, UMMZ 200586); Fayette County: 1.5 miles [2.4 km] N Ramsey (ISU 5); Fulton County: Summum (SIUC R-2366); Macon County: Decatur (INHS 9088); McLean County: Normal (BMNH 93.1.2.1, 93.1.2.2, UIMNH 4962); Lake Dawson, Moraine View State Park (ISU T703); Piatt County: White Heath (INHS 9007); Sangamon River bottoms near Monticello (UIMNH 2170); 2 miles [3.2 km] E Lodge (INHS 6684, 6779) Sangamon County: Lake Springfield, 6 miles [9.6 km] S Springfield (ISM 621866); Lake Springfield (ISM 622096, 622267); Pond at entrance to Lake Sangchris State Park (SIUC R-2368); Lake Springfield Wildlife Sanctuary (ISM 620543); Schuyler County:

Camp Emmanuel (INHS 10609); Vermilion County: Armstrong (INHS 9161); Will County: Northeast corner Crete township (FMNH 55562); 2 miles [3.2 km] S Crete (FMNH 65902).

The following data were recorded for each specimen: sex, snout-vent length, of dorsal spot numbers (left and right separately), lateral spots (left and right separately), sublateral spots (left and right separately), ventral spots, ventral scales, supralabial scales (left and right), infralabial scales (left and right), preocular scales (left and right), postocular scales (left and right), anterior temporal scales (left and right), posterior temporal scales (left and right), anterior scale rows, midbody scale rows, posterior scale rows, head length, greatest parietal-rostral length, parietal scale length, internarial distance, prefrontal suture length, and interocular distance. Anterior scale rows were counted one head-length from the posterior end of the parietal scale. Ventral scale rows were counted from the anal plate anteriorly.

Measurements were taken with dial caliper, and recorded to the nearest 0.01 mm. Head and scale measurements of each specimen were divided by the geometric mean (the nth root of the product of n measurements) for that specimen to standardize the values. Each animal over 200 mm SVL was dissected and stomach contents examined.

Principal Components Analysis and Canonical Discriminant Function Analysis were run on meristic data from all specimens. F tests were conducted on each character to determine normality of distribution. T tests determined if differences existed in any characters between animals from north and south of the Kankakee Lake Plain. These two clusters of populations are referred to as the northern and southern groups. Because all neonatal snakes examined were from the northern group, all analyses were repeated after excluding them. Because the canonical DFA needs a minimum of three groups for the program to plot a graph, a third group was created by removing all of the animals from south and west of the Shelbyville Moraine from the southern group. This area was not covered by the Wisconsin glacier and is biogeographically distinct. It contains the only Illinois populations in areas that were ice free during the Wisconsinan

RESULTS

Distribution and Habitat of *Clonophis kirtlandii* in Illinois

Clonophis kirtlandii was observed from only two of the 33 sites examined. Two adult males and one adult female were found in Effingham (Site no. 10) and one adult female at the pond at Lake Sangchris (Site no. 19). Evidence for 19 other populations was obtained but only eight of these are confirmed.

Data were obtained from 70 localities and were used to estimate the historical (Figure 1) and current (Figure 2) range of *C. kirtlandii*. Evidence predating the rangewide survey begun in 1985 (Wilsmann and Sellers, 1988) was used for Figure 1, and the remainder for Figure 2. The following is a list of the sites in Figure 2 and the most recent year *C. kirtlandii* was collected or cited: SW Adams Co., 1985 (Thurow, 1993); Camp Emmanuel, Schuyler Co., 1985 (Wilsmann and Sellers, 1988); Lake Springfield at entrance to wildlife sanctuary, Sangamon Co.,1985 (ISM 620543); East boat dock, Lake Sangchris State Park, Christian County, 1985 (ISM 691223); Carlé Woods, Des Plaines,

Cook Co., 1987 (T. Anton pers. comm.); Lake Paradise Spillway, Coles Co. 1987 (J. Tucker pers. comm.); Tinley Park, Cook Co., 1988 (Photograph SIUC R- 2461); Waterfall Glen, DuPage Co., 1989 (Ludwig et al., 1992); Swift Meadows, DuPage Co., 1989 (Ludwig et al., 1992); Orland Park, Cook Co.,1989 (SIUC R-2367); Goodenow Grove Forest Preserve, Will Co., 1988 (Photograph SIUC R-2459); Rochester, Sangamon Co., 1989 (T. Strole pers. comm.); 6 miles [9.6 km] NNE of Monticello, Piatt Co., 1990 (Photographs SIUC R-2462); Lake Sara spillway, Effingham Co., 1990 (M. Redmer, pers. comm.); Walnut Point State Park, Douglas Co., 1991 (Photograph SIUC R-2461); Summum, Fulton Co., 1992 (SIUC R-2366); Lake Sangchris pond, Sangamon Co., 1992 (SIUC R-2368); Kiwanis Park, Charleston, Coles Co., 1992 (E. Moll pers. comm.); and Effingham, Effingham Co., 1992 (UMMZ 200586).

Morphological Characteristics of Illinois *Clonophis kirtlandii*

Slight morphological variation was observed among the Illinois specimens of *C. kirtlandii*. Principle Components Analysis (PCA) was unable to distinguish specimens from north and south of the Kankakee Lake Plain (Figure 3). T tests revealed that northern and southern populations differ significantly in seven of 23 meristic characters: SVL, number of right and left lateral spots, ventral scales, left supralabial scales, left postocular scales, and left anterior temporal scales. The northern group had an average of three more right and left lateral spots. In addition, all eight non-meristic characters differed significantly. However, many neonatal snakes had abnormal head scutellation. All nonneonatal specimens lacked loreals and all had one preocular and two postoculars. Of 13 neonates examined, three possessed loreals, three had two right and left preoculars, one had three right and left preoculars, and three had three right and left postoculars. Since eleven of the neonates came from litters born to two northern group females, the neonates subsequently were excluded and the tests were repeated. The subsequent analysis showed that the same six meristic characters were significantly different in the two groups with the exception of ventral scale counts. Nine specimens from the northern group had five left supralabial scales and seven had five right supralabials. All remaining northern and all southern specimens had six right and left supralabials. Five northern group specimens had three left postoculars and four had two left anterior temporals. The remaining northern group and all southern group specimens had the typical condition of one left anterior temporal and two left postoculars. None of the non-meristic characters were significantly different between groups after neonates were removed and the data was standardized with the geometric mean. The cluster analyses then were rerun using only those five meristic characters with significant differences between northern and southern groups. The second PCA (Figure 3) did not separate the groups, nor did the second DFA (Figure 4).

Clonophis kirtlandii from Villa Grove have white venters instead of the typical red (Morris, 1975). The three specimens from this site had no distinctive scalation characteristics. This is apparently the only site where white-bellied *C. kirtlandii* occur. Smith (1961) mentions a specimen with a pale venter seen near St. Joseph, Illinois, but no vouchers from this area were found.

DISCUSSION

Kirtland's snake habitat certainly has been drastically reduced during the past century. A decline in the number of Illinois *C . kirtlandii* was first noted by Garman (1892, p. 215), who stated:

> "...ten years ago [it] was not uncommon along prairie brooks in the central part of the state. Tiling, ditching, and cultivation of the soil have destroyed its haunts and nearly exterminated it."

The remaining populations are in a few isolated islands of land that have been spared urbanization or agriculture. Former *C. kirtlandii* sites in Evanston (Grosse Point), Westmont, and Chicago (103rd and Western, School and Odell) are completely urbanized and *C. kirtlandii* is certainly extirpated there. Populations in the cities of Champaign-Urbana, and Bloomington-Normal have not been documented since the 1950's and appear to be extirpated as well. *Clonophis kirtlandii* was last reported from Champaign County in 1961 (Wilsmann and Sellers, 1988), and from McLean County in1966 (ISUT 703). Cliburn (1960) postulated *C. kirtlandii* to be approaching a natural extinction.

The highly disturbed nature of the remaining *C. kirtlandii* sites precludes in-depth analysis of the original habitat to which they were adapted. Some of the sites (e. g., Effingham) are surrounded by urban development and several populations of snakes exist in the midst of trash and debris in vacant city lots. Pristine sites in Illinois containing the original habitat for *C. kirtlandii* are unknown. The only common site characteristics were mowed grass, crayfish burrows, and a temporary or permanent source of water.

Many Kirtland's snake populations are in protected areas but even protected sites are vulnerable to harmful activities. Controlled burns, vehicular traffic, and mowing are all known to contribute to the mortality of snake populations. Minton (1972) found 18 road killed *C. kirtlandii* along a short (0.6 km) stretch of road in Indianapolis, IN. Six of the specimens examined in this study were road kills. The substitution of herbicide spraying for burning along railroad rights of way probably has been detrimental to *C. kirtlandii* populations.

In light of the apparent declines and extirpations of Illinois populations, *C. kirtlandii* should be classified as threatened. The remaining populations are Extant populations should be monitored closely to determine reproductive status. Management programs should consider limiting spring and fall mowing to midday or mowing only in the summer when *C. kirtlandii* are less likely to be active at the surface as suggested by Dalrymple and Reichenbach (1984) for Ohio populations of *Thamnophis radix.*

Successive visits are often required to confirm the existence of *C. kirtlandii* populations, so all unconfirmed sites should continue to be monitored for its presence. Continued surveys are strongly recommended as additional relict populations may still be located. Particular attention should be paid to central and northeastern Illinois sites since they were not adequately surveyed in this study. A detailed natural history study of *C. kirtlandii* is imperative before the status of individual populations can be determined.

ACKNOWLEDGMENTS

This study has benefited greatly from the advice and support of Ronald A. Brandon. I thank William G. Dyer for critically reviewing the manuscript. I am grateful to the following individuals and museums for lending specimens and providing information: Colin McCarthey (BMNH); Ron Vasile (CA); Alan Resetar (FMNH); Lawrence M. Page (INHS); Tim Cashatt (ISM); Lauren E. Brown (ISU); Douglas A. Rossman (LSUMZ); José P. Rosado (MCZ); W. Ronald Heyer (USNM); and Greg Schneider (UMMZ). Many individuals provided information on current and potential populations, especially Edward O. Moll, Eastern Illinois University, John K. Tucker, Illinois Natural History Survey, and Tom Anton, Field Museum of Natural History. Permission to conduct research and collect reptiles and amphibians was given by the Division of Natural Heritage, Illinois Department of Conservation (Permit nos. A-92.0089 and A-93.0023). This paper was drawn from a thesis submitted to Southern Illinois University at Carbondale in partial fulfillment of the M. S. degree. Funding for this project was provided by a U. S. Fish and Wildlife Service contract administered through the Division of Natural Heritage, Illinois Department of Conservation to Dr. Ronald A. Brandon. The IDOC is not responsible for the accuracy of the information presented in this paper.

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Table 1. Illinois sites examined for *Clonophis kirtlandii*, 1991-1993. Confirmed sites underlined.

Site No.	County	Locality	Dates visited
1	Adams	Bob Bangert Park, Quincy	7/12/91
2	Adams	2.4 km N Quincy	7/12/91, 10/19/91
3	Adams	Frazier Creek	7/12/91, 10/19/91
4	Bond	Keyesport Landing	9/22/91, 3/7/92
5	Brown	Siloam Springs State Park	7/13/91
6	Christian	Sangchris Lake State Park East Boat Dock	7/13/91, 9/30/91, 10/20/91, 4/11/92
7	Clinton	South Shore State Park	6/16/91, 7/13/91, 7/17/91, 4/19/92, 5/1/92
8	Clinton	Eldon Hazlet State Park	7/6/91, 9/22/91, 10/7/91, 11/1/91, 3/7/92
9	Douglas	Villa Grove	8/27/91, 10/26/91
10	Effingham	Neibrugge Oil Co. Henrietta St. & Fayette Ave	7/23/91, 5/2/92, 10/21/92, 4/20/93
11	Fayette	Caryle Lake Wildl Mgt. Area	9/22/91, 3/7/92
12	Fayette	Ramsey Lake St. Park	6/18/91, 7/23/91, 9/30/91, 4/19/92
13	Jasper	Sam A. Parr State Park	10/13/91
14	Lawrence	Red Hills State Park	10/13/91
15	Marion	Stephen A. Forbes St. Park	8/4/91, 4/24/92
16	Montgomery	Coffeen Lake	7/6/91
17	Sangamon	Lake Springfield	9/30/91, 10/20/91, 4/11/92, 5/12/92
18	Sangamon	Sangchris Lake Spillway	9/30/91
19	Sangamon	Sangchris Lake Pond	9/30/91, 10/20/91, 4/11/92, 5/12/92
20	Schuyler	Lake Emanuel	7/13/91, 10/19/91, 5/12/92
21	Schuyler	Weinberg-King State Park	10/19/91
22	Shelby	Hidden Springs State Forest	6/18/91
23	Washington	Washington Co. Cons. Area	7/17/91, 9/30/91, 3/7/92
24	DuPage	Swift Meadows	7/3/92, 5/20/93
25	DuPage	Warrenville Grove	7/3/92
26	Coles	Charleston, 3 Sites	10/21/92
27	Coles	Lake Paradise Spillway	5/2/92
28	Effingham	Bean Implement	5/2/92
29	Cook	Carlé Woods	5/23/93
30	Cook	Palos Hills	5/20/93
31	Douglas	Walnut Point S. P.	5/19/93
32	Coles	Lake Charleston Spillway	4/20/93
33	Coles	Fox Ridge State Park	4/20/93

Figure 1. Illinois reports of *Clonophis kirtlandii* prior to 1985. Solid circles = confirmed reports, open circles = unconfirmed reports from literature, open triangles = anecdotal reports

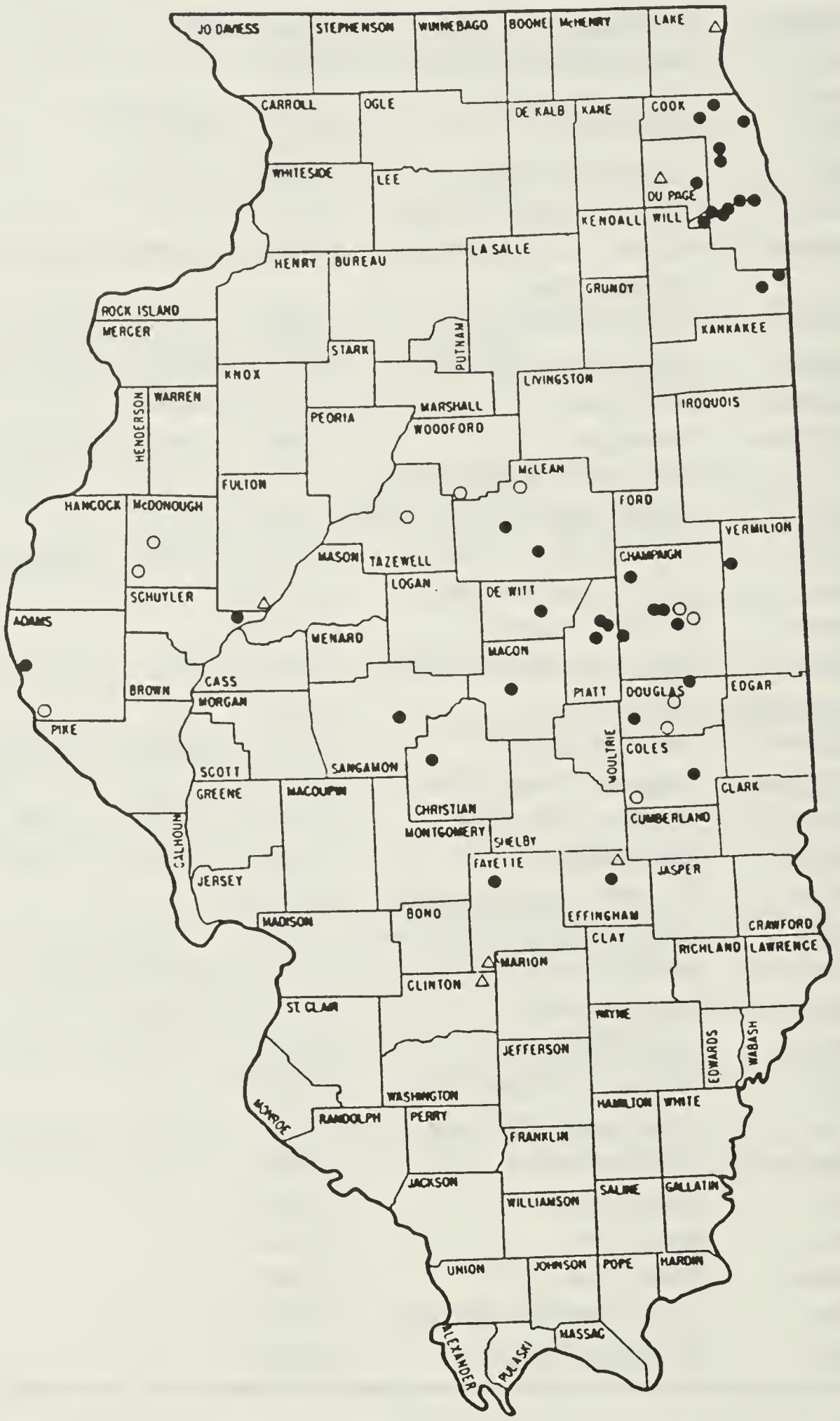


Figure 2. Illinois reports of *Clonophis kirtlandii* since 1985. Solid circles = confirmed reports, open circles = unconfirmed reports, open triangles = anecdotal reports. Sources are Wilsmann and Sellers, (1988), and the present study.

Figure 3. Principal components analysis of morphological characters of Illinois *Clonophis kirtlandii* excluding neonate animals under 125 mm snout-vent length.

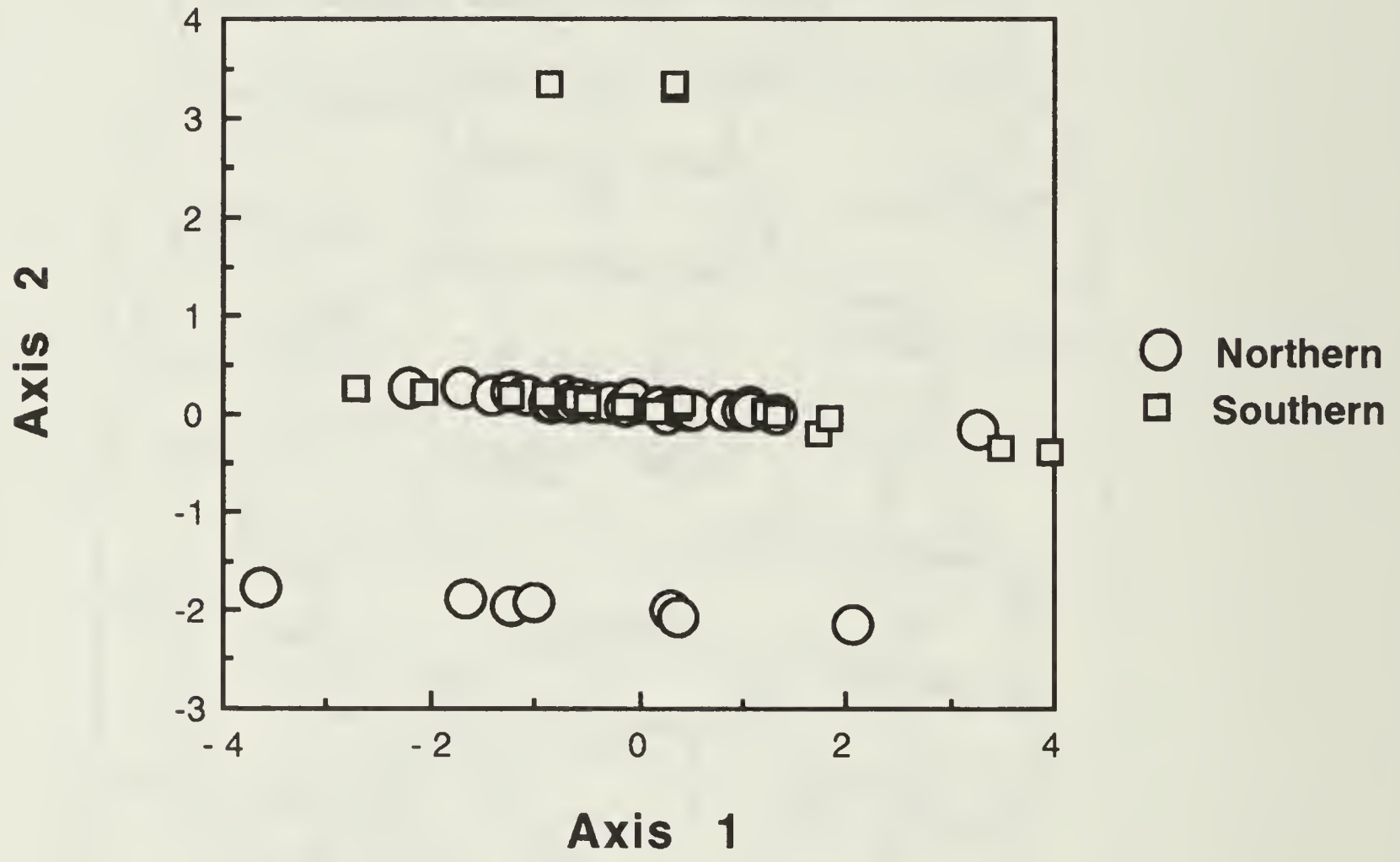
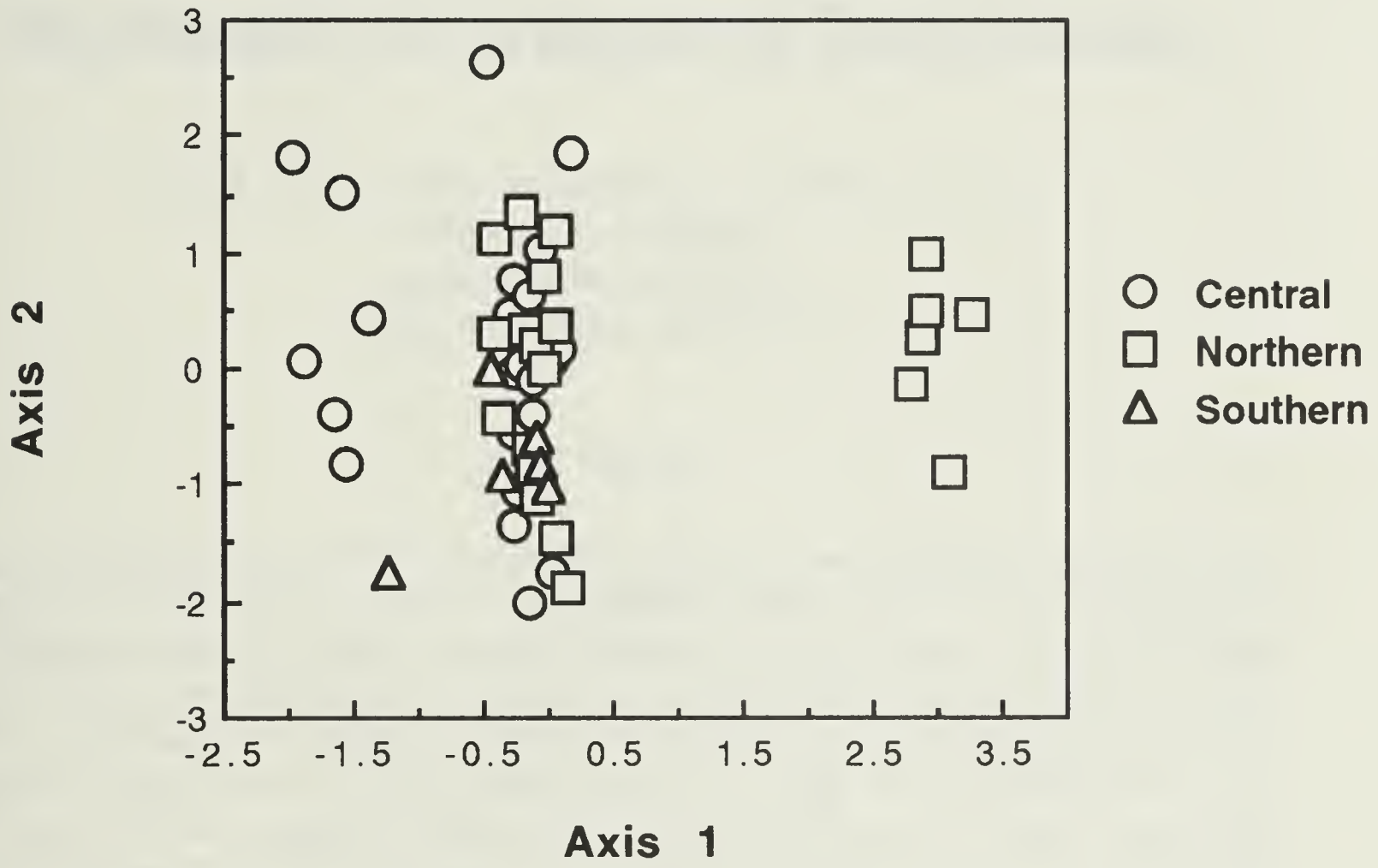


Figure 4. Canonical discriminant functions analysis of morphological characters of Illinois *Clonophis kirtlandii* excluding neonate animals less than 125 mm snout-vent length.



Transactions of the Illinois State Academy of Science
(1994), Volume 87, 3 and 4, pp. 165-170

Helminths of the Gastrointestinal Tract of Raccoons in Southern Illinois with Management Implications of *Baylisascaris procyonis* Occurrence

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ABSTRACT

The gastrointestinal tracts of 60 raccoons (*Procyon lotor*) were examined for helminths. Six species were found: four species of nematodes (*Arthrocephalus lotoris, Physaloptera rara, Gnathostoma procyonis,* and *Baylisascaris procyonis*); one species of cestode (*Mesocestoides variabilis*); and one species of acanthocephalan (*Macracanthorhynchus ingens*). *Baylisascaris procyonis* has been implicated in the decline of woodrat populations throughout the northeast United States. As such, this parasite also may have been a factor in the extirpation of the eastern woodrat (*Neotoma floridana*) throughout most of southern Illinois. The frequency occurrence of *Baylisascaris procyonis* in our sample was unexpectedly low, 3 of 60 raccoons (5.0%), and suggests that reintroduction of eastern woodrats to formerly occupied sites in southern Illinois may not be adversely affected by this parasite.

Key Words: *Baylisascaris procyonis*, eastern woodrat, helminths, raccoon, parasites, *Procyon lotor*, southern Illinois

INTRODUCTION

Raccoons (*Procyon lotor*) are common throughout the contiguous United States. They are adapted to a variety of habitats and are economically important, as they are trapped and hunted for sport and pelts. Because they are omnivorous and widely distributed, raccoons have been the subject of numerous parasite surveys. Depending on the geographic region, a variety of parasite species may occupy the gastrointestinal tract of raccoons. In Illinois, Barnstable and Dyer (1974) found 9 species of helminths from 36 raccoons from 7 southern Illinois counties. Snyder and Fitzgerald (1985a) found 14 species of helminths in 245 raccoons trapped within a 161 km radius of Farmington, Fulton County, Illinois.

Baylisascaris

Among the helminths reported in raccoons, one species of special interest is *Baylisascaris procyonis* (Nematoda: Ascarididae) (Sprent 1968). Barnstable and Dyer (1974) found this species (reported as *Ascaris columnaris*) in 64% of 36 raccoons. Snyder and Fitzgerald (1985b) considered these to be *B. procyonis*. Snyder and Fitzgerald (1985b, 1987) found

that approximately 93% of juvenile raccoons in northern Illinois contained *B. procyonis* in the gastrointestinal tract, as did 55.3% of adults. *Baylisascaris procyonis* is the only ascarid species found in raccoons. Ascarid nematodes previously reported in raccoons, including *Ascaris alienata, Ascaris columnaris, Ascaris procyonis*, and *Toxascaris procyonis* are considered synonyms of *Baylisascaris procyonis* (Sprent 1968). Most *B. procyonis* found in adult raccoons are immature and it is believed that adult worms are expelled (Kidder et al. 1989). All developmental stages of the parasite occur in juvenile raccoons (Snyder and Fitzgerald 1985b). Besides being potentially fatal to humans, this parasite has been reported as a possible cause in the decline of woodrat (*Neotoma floridana*) populations (Eastern Woodrat Workshop 1986).

Woodrats as an Intermediate Host

Woodrat populations have been declining in Virginia, West Virginia, Pennsylvania, New York, Connecticut, New Jersey, Ohio, Indiana, and Illinois. Recent population reductions of woodrats have been attributed to possible infection by *B. procyonis* (Eastern Woodrat Workshop 1986). Woodrats ("packrats") collect a variety of material, including animal feces, and bring it back to their nests. This behavior could make them more susceptible to *B. procyonis*, for which they are an intermediate host. Infection leads to lethargy, loss of muscle control, decreased head control, torticollis, ataxia, and nystagmus, progressing to stupor, extensor rigidity, coma, and death (Kazacos et al. 1981; Kazacos 1983*a*, 1986; Kazacos and Boyce 1989). Besides woodrats, *B. procyonis* has been shown to cause central nervous system disease in 19 species of mammals and 13 species of birds (Kazacos and Boyce 1989).

The eastern woodrat historically has occupied the Shawnee Hills region of southern Illinois. Nawrot and Klimstra (1976) found evidence of past woodrat occupation at 24 sites in southern Illinois. The species has only recently been extirpated from several sites and the only existing population in Illinois currently is in Pine Hills, Union County. This is an isolated, remnant population isolated from populations in other states, as the Shawnee Hills are bordered by the Mississippi and Ohio rivers. The eastern woodrat is listed as endangered in Illinois (Herkert 1992). The U.S. Forest Service has recently discussed the possibility of reintroducing the eastern woodrat into the eastern portion of the Shawnee National Forest where historic woodrat sites exist. Because *B. procyonis* may be a problem in future reintroductions of the woodrat in southern Illinois, it is important to assess the prevalence of this parasite in raccoons from southern Illinois.

Objectives

The purpose of this study was to determine the prevalence of helminths in the gastrointestinal tract of raccoons - with emphasis on *Baylisascaris procyonis*. Data on the occurrence of *B. procyonis* in Pope County was needed to determine the feasibility of reintroduction of woodrats to one or more historic sites. Information from Pine Hills was collected to determine whether this parasite could be a factor in the decline of the remaining woodrat population in Illinois.

MATERIALS AND METHODS

Raccoons were collected from 19 November to 18 December 1992 from two sites in Pope County - the Benham Hill area (n = 23), approximately 6 km southeast of the Lusk Creek Canyon Wilderness Area, and the Dixon Springs Recreation Area (n = 7). Thirty raccoons were taken immediately adjacent to Pine Hills, Union County, from 20 April to 21 July 1993, to provide a total sample of 60 raccoons.

Laboratory Procedures

All raccoons were sacrificed in a humane manner, weighed to the nearest 0.1 kg, and stored (1 to 5 days) in a refrigerator at 7 degrees C. Age estimation (juvenile or adult) was calculated using body weight, and the degree of ossification of the epiphyseal cartilage of the radius and ulna (Sanderson 1961). An incision from the throat to the anal region was made and the gastrointestinal tract removed (esophagus, stomach, small intestine, and large intestine/ rectum). Each component of the gastrointestinal tract was separated, transferred to a container of physiological saline solution (8g/L), opened longitudinally, scrapped with a glass slide, and examined for helminths with the aid of a dissecting microscope. Helminths were isolated and prepared for fixation and storage in ethanol or formalin.

Nematodes were fixed by placing them in a solution of hot 70% ethanol and glycerin. They were then transferred to a glass dish containing alcohol-glycerine. The cover was placed on top with a paper towel between the cover and the glass dish. The alcohol was allowed to evaporate, leaving the nematodes in pure glycerine ready for observation as temporary mounts. Cestodes were fixed in formalin for 1 hour, washed in distilled water for 1 hour, and placed in Harris' hematoxylin solution overnight, followed by a rinse in distilled water. Specimens were then placed in 35%, 50%, and 70% alcohol successively for 1 hour each, destained in acid alcohol, placed in alkaline alcohol, and dehydrated in 85%, 95%, and 100% alcohol successively for 1 hour each. These were then transferred to a clearing agent and mounted on glass slides. Acanthocephalans were placed in distilled water until the proboscis was fully extended. They were then fixed in an alcohol-formalin mixture or Boulin's fluid for a few hours or overnight. They were then transfered to 70% ethanol where the body wall was pricked and left overnight. Prevalence (number of individuals of a host species infected with a particular parasite species divided by the number of hosts examined) of parasites was recorded for Pope County, Pine Hills, and for the overall sample.

RESULTS AND DISCUSSION

Six species of helminths - *Physaloptera rara, Arthrocephalus lotoris, Gnathostoma procyonis, Baylisascaris procyonis, Mesocestoides variabilis*, and *Macracanthorhynchus ingens* - were found. All have been reported previously from raccoons. No trematodes were found.

Nematoda

Physaloptera rara Hall and Wigdor, 1918 was the most prevalent parasite found and occurred in 32 (53.3%) raccoons; 19 (63.3%) from Pope County and 13 (43.3%) from Union County. It was found in the esophagus, stomach, and small intestine. Barnstable

and Dyer (1974) found 69.4% of 36 raccoons were infected by *P. rara* in Illinois, and it has been reported in equally high frequencies in previous studies (Bafundo et al. 1980; Cole and Shoop 1987; Robel et al. 1989; Richardson et al. 1992).

Arthrocephalus lotoris (Schwartz, 1925) was found in the small and large intestine of 19 (31.7%) raccoons of both sexes and close to equal proportions in Pope County (30.0%) and Union County (33.3%). This parasite is widely distributed throughout the contiguous United States. In Illinois, Leigh (1940) found this species in 2 of 6 raccoons, while Barnstable and Dyer (1974) found it in 52.8% of their sample.

Gnathostoma procyonis Chandler, 1942 was found in 7 (11.7%) raccoons. This parasite was often found in groups embedded in the mucosa of the stomach. Barnstable and Dyer (1974) reported it from only 2 of the 36 raccoons (5.6%) they examined.

Baylisascaris procyonis was not conclusively identified due to the absence of males. All ascarids found were females, which do not possess perianal roughened patches. These roughened patches are present only in males and are diagnostic of the genus *Baylisascaris* (Sprent 1968). However, as noted, the only ascarid nematode known in raccoons is *B. procyonis*. Therefore, we are confident that the ascarids found in the small intestine of 3 juvenile raccoons (2 males and 1 female) from Pope County were *B. procyonis*. The 5% occurrence in our study was substantially lower than the 63.9% incidence (reported as *Ascaris columnaris*) found by Barnstable and Dyer (1974).

Cestoda

One species of tapeworm was recovered. *Mesocestoides variabilis* Mueller, 1927 was found in the small intestine of 20 (33.3%) raccoons; 12 from Pope County and 8 from Union County. *Mesocestoides variabilis* is the only species in this genus found in raccoons. In Illinois, Barnstable and Dyer (1974) recovered *Mesocestoides* in 9 of 36 (25.0%) raccoons, and Snyder and Fitzgerald (1985*a*) found it in 71 of 245 (29.0%) raccoons.

Acanthocephala

Macracanthorhynchus ingens Meyer 1932 was the only acanthocephalan found in the raccoons examined. It occurred in the large and small intestines of 20 (33.3%) raccoons of both sex and age categories. It was present in 40.0% of the Pope County sample and in 26.7% of the Union County sample. In Illinois, Barnstable and Dyer (1974) recovered this species in 5 of 36 (13.9%) raccoons, and Snyder and Fitzgerald (1985*a*) recovered it in 11 of 245 (4.5%) raccoons.

Of the 60 raccoons sampled, 1 (1.7%) had no parasites, 28 (46.7%) had a single species of parasite, 21 (35.0%) had 2 parasite species, and 10 (16.7%) raccoons had 3 parasite species. Considering the 28 raccoons with only one species of parasite, *P. rara* occurred in 15 (53.6%).

Variation in *Baylisascaris procyonis* Occurrence and Management Implications

Based on previous studies with sample sizes ≥ 60 raccoons, there appears to be a latitudinal gradient in the frequency of occurrence of *B. procyonis*, with low or no occurrence in more southern latitudes (Jordan and Hayes 1959; Harkema and Miller 1964; Johnson 1970; Schaffer et al. 1981). Also, the success of some parasitic helminths depends on the variety of intermediate and paratenic hosts available (Cheng 1973). Diversity of hosts depends on the extent of habitat diversity available. Thus, variation in occurrence of *B. procyonis* also may depend on local habitat conditions and topography (Bafundo et al. 1980; Schaffer et al. 1981; Jones and McGinnes 1983). Both latitude and local conditions could be factors in the low frequency occurrence of *B. procyonis* in this study.

Based on our results, *B. procyonis* does not currently appear to be a factor in the population dynamics of the Pine Hills woodrat population. Also, it would appear feasible to reintroduce eastern woodrats into one or more historic sites of the Shawnee National Forest. However, the eggs of *Baylisascaris* can be viable for several years with adequate moisture (Kazacos and Boyce 1989). Therefore, if and when a reintroduction site is designated, raccoon latrine sampling should be done (Kazacos 1983*b*) to determine the prevalence of *Baylisascaris* eggs in the reintroduction area. This would be less expensive and time consuming than collecting raccoons, and would give more site-specific information.

ACKNOWLEDGMENTS

Funding for this study was provided through a contract with the U. S. Forest Service. We thank Mike Spanel and Steve Widowski, Shawnee National Forest, for their assistance and support of this project. We also thank Dean Corgiat and David Blumenstock for assistance trapping raccoons, and Kris Alden for help in the laboratory. George Waring provided helpful comments on an earlier draft on the manuscript.

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Transactions of the Illinois State Academy of Science
(1994), Volume 87, 3 and 4, pp. 171-174

Microsternus ulkei (Crotch) (Coleoptera: Erotylidae), A Western Extension of its Range and First Record from Illinois

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ABSTRACT

Microsternus ulkei (Crotch) is reported from Wabash County, Illinois, representing the first record from Illinois and a western extension of its range. *Microsternus ulkei* is now known from Pennsylvania, Maryland and North Carolina in the east to Kentucky and Illinois in the west. Known fungal hosts of *M. ulkei* and other aspects of its biology are discussed.

RESULTS AND DISCUSSION

Microsternus ulkei (Crotch) is the only New World member of a genus which includes 15 species of Asiatic distribution (Chûjô & Chûjô 1988). The very short and wide mesosternum, which gives the genus its name, is unique among North American Erotylidae. Dorsally, the color pattern is equally distinctive, with a black or piceous head and pronotum, and red elytra; each elytron bearing four piceous spots (Fig. 1). Once recognized as an erotylid, this beetle is unmistakable.

Despite these distinctive characteristics, *M. ulkei* is rare in collections. In preparing his monograph on the North American Erotylidae, Boyle (1956) examined only 105 specimens and we (Goodrich & Skelley 1991) examined only 91 prior to preparation of Part I of our "Erotylidae of Illinois." Most of the above described specimens were old museum specimens with meagre collection data. To illustrate: of the 105 specimens seen by Boyle in the 1950's, 69 were labeled only "Ky"; of the 91 specimens we saw in preparing our paper, only 17 had been collected since 1940, and the majority were from 19th Century collections.

Boyle (1956) identified specimens of *M. ulkei* from Kentucky, Ohio, Pennsylvania, Maryland and North Carolina. Blatchley (1910) had earlier reported this species from Posey and Crawford counties in Indiana. In addition to these state records, we (Goodrich & Skelley 1991) identified specimens from West Virginia and two specimens from Monroe County, Indiana, about 97 Km east of the Illinois border. Because of the specimens collected near Illinois (Posey County borders southeastern Illinois) we (Goodrich & Skelley 1991) suggested that *M. ulkei* was likely to occur in Illinois. Subsequent to our 1991 publication, a specimen from Parke County, Indiana, was identified. Parke County is located in western Indiana, near the Illinois border. However,

until this year, despite extensive collecting in fungi and under bark, plus year-long operation of Malaise and flight traps in eastern and southern Illinois, no specimens of *M. ulkei* had been taken in Illinois.

On April 4, 1993, a light-weight Malaise trap with "wet" head, similar to the type described by Townes (1972), was placed in a wooded valley five Km southeast of Allendale in Wabash County, Illinois (NE quadrant of section 19). The trap site slopes down to the Wabash River floodplain and is in a second growth deciduous forest. Trap samples were collected weekly and the Erotylidae sorted out from the large mass of other insects collected. Among the Erotylidae trapped during 1993 were three specimens of *Microsternus ulkei*, collected during the following time periods: 19-25 April 1993 (1); 25 April-2 May 1993 (1); 2-9 May 1993 (1). These records are the first from Illinois and are the farthest west in North America. Although the Malaise trap was serviced continuously on a weekly basis until mid-December 1993, no additional specimens were collected. Woodland collecting under bark and in fungal habitats in the area near the trap also failed to produce additional specimens.

Information on the biology of *M. ulkei* is meagre. Boyle (1956) found no biological data on the collection labels of the 105 specimens he examined. Dury (1878) provided a brief description of the structure and development of the immature stages and described the host as *Polypora* (not a very specific identification in 1878, as it could apply to a wide range of polypores). Blatchley (1910) included a record for *M. ulkei* from *Polyporus cuticularis* (now known as *Inonotus cuticularis*). In addition, we (Skelley, Goodrich & Leschen 1991) have records of two specimens from *Polyporus gilvus* (now known as *Phellinus gilvus*) and four specimens taken "near *Stereum ostrea*." Michael C. Thomas (personal communication) reports collecting *M. ulkei* under bark of an old beech stump. In east central Illinois, I have frequently searched under the bark of dead beeches and other dead trees bearing the sporocarps of *Inonotus* and *Phellinus* without finding these beetles or their larvae.

In addition to the collection dates reported above for Illinois, I have records of adult specimens taken in the northeastern United States between 6 April and 4 September. The larva is illustrated in Lawrence (1991). I would very much like to see any other specimens of this species, particularly if they are associated with host fungi or are collected in Illinois.

ACKNOWLEDGMENTS

I am pleased to acknowledge the work of Paul Skelley of the University of Florida for his preparation of the habitus drawing of *M. ulkei*, and the contribution of Gary Adams of Allendale, Illinois, who allowed me to place the Malaise trap in woods on his property and who serviced the trap on a regular basis during 1993. This research was partially funded by a grant from the Eastern Illinois University Council of Faculty Research.

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Fig. 1. Dorsal habitus of *Microsternus ulkei* (Crotch). (Line = 2.0 mm)

Transactions of the Illinois State Academy of Science
(1994), Volume 87, 3 and 4, pp. 175-185

Morphological Variation in White-Tailed Deer From Illinois

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ABSTRACT

We examined 361 adult, female white-tailed deer (*Odocoileus virginianus*) skulls to elucidate patterns of morphological variation within Illinois, and to assess the subspecific status of regional Illinois herds with special emphasis on southern Illinois. Deer in Illinois exhibited a latitudinal cline consistent with Bergmann's ecogeographic rule, although a character shift between southern and southcentral Illinois was apparent. Illinois samples were not distinct from specimens representing *O. v. borealis* and larger *O. v. macrourus*. Based upon our findings, continued inclusion of Illinois within the *O. v. borealis* range is warranted.

Key Words: *Odocoileus*, subspecies, morphometry

INTRODUCTION

White-tailed deer from Illinois have been included within the range of the large northern woodland white-tailed deer (*O. v. borealis* [Miller]). Another large form, the Kansas white-tailed deer (*O. v. macrourus* [Rafinesque]), occupies the central plains states west of the Mississippi River, and a smaller race, the Virginia white-tailed deer (*O. v. virginianus* [Zimmerman]), is found southeast of the Ohio River (Kellogg 1956; Halls 1978; Hall 1981) (Fig. 1). White-tailed deer were probably eliminated from Illinois by the early 20th century, the last reported sightings coming from southern Illinois around 1910 (Pietsch 1954; Calhoun and Loomis 1974).

The reintroduction of deer into Illinois began in the 1930s with animals primarily from Michigan and Wisconsin, and others of unknown origin (Pietsch 1954). Reintroductions using animals of differing stock, game farm escapes, natural emigration, and the possibility of surviving remnants of the original herds have obscured the taxonomic picture of deer in Illinois as well as other regions (Kellogg 1956; Halls 1978; Smith et al. 1984).

Ritchie (1970) compared deer from northern and southern Illinois and found that the latter exhibited smaller masses and basal antler beam diameters than the former. He believed these differences resulted from southern deer surviving on a lower nutritional plane. Harder (1980) compared the relationship between body mass and reproductive rates among populations from the northern United States and found that populations with high female

body mass had high reproductive rates. The exception was for deer from Crab Orchard National Wildlife Refuge in southern Illinois which had high fetal rates albeit low body mass. Nelson and Woolf (1985) suggested these differences in size reflect genetic rather than nutritional differences based on the productivity and good physical condition of deer on Crab Orchard Wildlife Refuge (Roseberry and Klimstra 1970; Nelson 1984).

Southern Illinois occupies a unique position with regard to the classification of *O. virginianus*, lying between 2 major river systems which form the boundaries of 3 purported subspecies, with unrestricted gene flow to the north. We studied the morphometric relationships among samples from selected regions of Illinois, and examined the association between these specimens and samples representing the 3 purported subspecies of *O. virginianus*, with special emphasis on southern Illinois.

MATERIALS AND METHODS

Cranial measurements were taken from 361 undamaged adult (≥2 years old), female white-tailed deer skulls. Most skulls were collected from hunter-harvested animals, however museum specimens were also examined (Appendix I). Restricting analyses to adult females reduced the effects of age-related variation, and removed the effects of secondary-sexual variation.

Initial collections from Illinois included northwestern (Carroll, Jo Daviess, and Whiteside counties), westcentral (Adams and Pike counties), and southern (Alexander and Williamson counties) regions of the state (Fig. 1). These areas are characterized by rolling to rugged uplands dissected by forested stream and river corridors, and tracts of contiguous forested habitat. Preliminary sampling also included the prairie region of eastcentral Illinois (Dewitt, Livingston, McLean, and Piatt counties), an area distinctly different with respect to habitat, land use, and physiography. This region is characterized by flat, intensively-farmed terrain with isolated small forests. Subsequent collections included southcentral Illinois (Jefferson and Washington counties) and Effingham county, in order to examine for clinal variation between central and southern Illinois.

Crania from geographically disjunct areas within the accepted range (excluding Illinois) of *O. v. borealis*, *O. v. macrourus*, and *O. v. virginianus* were also examined (Fig. 1). These included: for *O. v. borealis*, northeastern Minnesota, southcentral Michigan, southwestern Pennsylvania, and southern Maine (type locality Bucksport, Hancock Co.); for *O. v. macrourus*, northeastern Kansas (type locality near Wakarusa Creek, Douglas Co.), Arkansas (primarily northcentral), and southeastern Missouri; for *O. v. virginianus*, eastcentral and westcentral Virginia (type locality Virginia), southwestern South Carolina and southwestern Tennessee. More detailed information on sampling localities is provided in Appendix I.

Ages of specimens were determined according to tooth eruption and wear (Severinghaus 1949). Cleaned and dried crania and rami were measured with a Helios dial micrometer (0.05 mm calibration) and a Dunlap measuring board (1.0 mm calibration). Twenty cranial measurements taken are described by Levengood (1991). Evaluations of univariate and multivariate normality, outliers, and homogeneity of variance-covariance matrices were satisfactory. Specimens were grouped by geographic region. An alpha level of 0.01

was selected for univariate and multivariate analyses of skeletal characters. Testing for differences between means was accomplished using the GLM procedure of SAS (SAS Institute Inc. 1985); multiple comparisons were performed using the Tukey/Kramer method.

Stepwise discriminant function and canonical-variate analyses were used to identify and separate groups using the DISCRIMINANT procedure of SPSSX (SPSSX Inc. 1983). Stepping was accomplished using the MAHAL specification of the METHOD subcommand. This procedure selected a subset of the original variables which maximizes Mahalonabis' distance between the two closest groups. F-to-enter and F-to-remove were the default value of 1.0. Prior probabilities were set equal to sample sizes to account for disparity in group size. A distance phenogram was constructed based on a UPGMA analysis of standardized character means using CLUSTER and TREE of SAS (SAS Institute, Inc 1985).

RESULTS

Univariate comparisons of 272 *O. virginianus* skulls from Illinois revealed 15 characters with significant levels of geographic variability (Table 1). Deer from southern Illinois averaged smaller than specimens from the westcentral, northwestern, eastcentral, and southcentral portions of the state for 12, 11, 9, and 5 cranial measurements, respectively. Specimens from Effingham County, Illinois, were significantly larger for 10 characters, when compared to skulls from the southern region. Comparisons between more northerly (southern Illinois excepted) regions of the state were less conclusive.

Six characters increased in size from southern Illinois northward through southcentral, Effingham County, and eastcentral Illinois (Table 1). Specimens from eastcentral Illinois, however, averaged larger or equal to those from northwestern Illinois for 15 measurements, and were larger than all Illinois regions for 11 characters. These patterns were apparent for palatal length (PALATLEN), the most geographically variable of 20 characters examined (Fig. 2). Correlations between PALATLEN and the remaining 19 characters ($r = 0.32 - 0.42$, $\underline{P} < 0.001$) suggested similar trends for all craniodental measurements. A character shift or step was apparent between southcentral and southern Illinois.

In order to examine the status of regional Illinois deer herds relative to specimens representing *O. v. borealis*, *O. v. macrourus*, and *O. v. virginianus*, a stepwise discriminant function analysis was performed using 20 cranial measurements from 361 specimens as predictors of membership in 9 groups (Fig. 3a); southern Illinois specimens were considered unknowns. Seven functions were derived, but only the first 3 functions were significant ($X^2_{42} = 66.6$, $\underline{P} = 0.01$). The first, second, and third functions accounted for 58, 16, and 10 percent of the between-group variability, respectively.

Eighteen characters in combination were useful in distinguishing groups. Length of the lower molariform tooth row (0.7), length of the upper molariform tooth row (-0.5), and palatal length (0.5) were among the most important discriminators on the first function; condylobasal length (-1.9), palatal length (1.3), and length of the upper molariform tooth row (1.1) were the primary distinguishing variables on the second function.

In a bivariate plot of canonical-variate scores samples from northwestern, westcentral, eastcentral, Effingham County, and southcentral Illinois overlapped considerably and are enclosed within a single polygon (Fig. 3a). The southern Illinois and combined Illinois polygons were not distinctive. The *O. v. borealis* sample coincided with 61, 58, and 41 percent of the combined Illinois, *O. v. macrourus*, and southern Illinois polygons, respectively. The 2 Illinois polygons in combination overlapped 81 percent of the *O. v. borealis* sample; of the Illinois samples, the southcentral Illinois centroid (C) was farthest from the *borealis* centroid (B), while the westcentral Illinois centroid (W) was in closest proximity to the latter. The *O. v. virginianus* and *O. v. macrourus* samples exhibited 31 and 74 percent congruence, respectively, with the *O. v. borealis*, combined Illinois, and southern Illinois samples. The *O. v. macrourus* specimens overlapped 66 percent of the *O. v. virginianus* sample.

Correct classifications ranged from 31.6 (Effingham Co. IL) to 74.4 percent (*O. v. virginianus*). Twenty (62.0%), 14 (40.0%), and 1 (10.0%) specimen(s) of misclassified *O. v. borealis*, *O. v. macrourus*, and *O. v. virginianus*, respectively, were categorized as Illinois specimens. Sixteen (80.0%) misclassified *O. v. borealis* were grouped with northwestern or westcentral Illinois. Overall, 83% of *O. v. borealis* were classified as *O. v. borealis* (including Illinois). Of 45 Illinois specimens misclassified as *O. v. borealis*, *O. v. macrourus*, or *O. v. virginianus*, 30 grouped with *borealis*; the remainder were classed as *O. v. macrourus*.

Thirty-two (54.2%) southern Illinois specimens (classed *a priori* as unknowns) grouped with Illinois skulls, primarily those from northwestern and westcentral Illinois. A large proportion were categorized as *O. v. borealis* (25.4%) or *O. v. macrourus* (18.6%); only 1 specimen grouped with *O. v. virginianus*.

A phenogram based upon standardized character means produced two primary groups, 1 including smaller specimens representing *O. v. virginianus*, as well as *O. v. macrourus* from Arkansas, the other containing the larger *O. v. borealis*, Illinois, and *O. v. macrourus* (Kansas and Missouri) specimens (Fig. 3b). Within the latter group, 2 secondary groups were distinguished, 1 comprised of samples from Missouri, Pennsylvania, and southern Illinois, the other consisting of the remaining regions. Samples from Missouri, Pennsylvania, and southern Illinois were intermediate in size between the 2 morphotypes for most characters (Levengood 1991).

DISCUSSION

According to Bergmann's Rule, homeotherms at higher latitudes should be larger than their counterparts at lower latitudes. The surface-to-volume law is most often invoked to explain this phenomenon. Larger animals have a smaller surface-to-volume ratio, and should therefore be more efficient at conserving heat. White-tailed deer are thought to exhibit clinal variation consistent with this biogeographic rule (Baker 1984). Based upon analysis of cranial characters, deer in Illinois displayed a general pattern of variation consistent with Bergmann's Rule, although a step between southcentral and southern portions of the state was apparent. According to Endler's (1972) ecotone model, abrupt environmental changes need not be large to produce steep clines in character gradients.

The degree of geographic differentiation would be increased by stronger selection pressures and decreased by stronger gene flow. Thus, deer could be subject to strongly divergent selection pressures in the face of apparent gene flow (e.g. across the Southern Till Plain - Shawnee Hills Divisions in southern Illinois).

The large degree of overlap and misclassification among *O. v. borealis* and the Illinois samples agrees with the original classification of *O. v. borealis*, which included all of Illinois (Hall 1981). Our results suggest that *O. v. borealis* and *O. v. virginianus* are morphologically distinct forms, and that deer from Illinois (including southern Illinois) are assignable to *O. v. borealis*. The large degree of overlap between *O. v. macrourus* and *O. v. borealis* was primarily due to the misclassification of a relatively large number (79% of misclassifications) of *O. v. macrourus* specimens as *O. v. borealis*. Further discussion of relationships among subspecies is beyond the scope of this paper.

In our phenetic analysis, Illinois specimens grouped with the larger *O. v. borealis* and *O. v. macrourus* (Kansas and Missouri) specimens, further substantiating our conclusions. Missouri, Pennsylvania, and southern Illinois formed a secondary cluster within that cluster comprised of the large morphotypes. The southern Illinois and southeastern Missouri sampling localities were geographically close. The Illinois and Missouri herds are separated by the Mississippi River, which provides a partial barrier to gene flow. While it is likely that some genetic interchange is occurring, these herds are also constrained by similar environmental conditions. This argument (parapatry) does not explain the relationship between deer from southern Illinois and southeastern Missouri and the Pennsylvania sample. Deer from these regions may to some extent share a common genetic background, because deer from Michigan were used in restocking programs in Illinois, Missouri, and Pennsylvania (Robb 1959; Pietsch 1954; W. Shope pers. commun.). The degree to which these introduced genes were swamped or lost through competition with better-adapted native stock remains unknown.

ACKNOWLEDGMENTS

We would like to convey our appreciation to the many biologists, check station personnel, and students who helped with the collection and/or preparation of specimens, as well as the hunters who provided these specimens. We would also like to thank those curators/collection managers who kindly loaned specimens in their charge. Funding was provided by the Illinois Department of Conservation through Federal Aid in Wildlife Restoration Project W-63-R(SI), Study IV.

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Table 1. Univariate comparisons of adult female *Odocoileus virginianus* skulls from Illinois. Measurements are mean ± S.D. in millimeters. Like superscripts denote means not different by Rukey/Kramer multiple comparisons test ($P < 0.01$).

Character	Northwestern Illinois (N=62)		Westcentral Illinois (N=71)		Eastcentral Illinois (N=26)		Effingham Co. Illinois (N=19)		Southcentral Illinois (N=20)		Southern Illinois (N=74)		F-value*
GREATLEN	283.1A,B	8.5	279.2A	7.8	287.8B	10.3	281.2A,B	11.7	278.0A	8.9	268.3	9.3	27.1**
CONDYLO	273.1A,B	7.6	270.2A,B	8.4	276.8A	9.3	272.7A,B	10.7	267.8B	9.1	259.0	9.3	26.1**
NASALEN	97.2A	5.7	93.8A	5.5	96.7A	7.4	95.1A	6.7	94.1A	6.0	87.1	5.2	24.5**
NASALWID	18.2A	1.8	17.5A	2.0	18.2A	2.2	17.1A	1.6	17.5A	2.0	17.7A	1.9	1.7
INTER	60.7A,B	2.7	61.3B	3.4	62.2B	2.8	60.1A,B	4.4	59.1A,B	3.3	59.4A	3.1	5.0**
ZYGOMA	109.1A	3.4	109.3A	3.4	110.1A	3.8	107.7A	5.7	107.0A	4.3	107.8A	4.2	2.9
PALATLEN	181.0A	6.2	177.7A	6.3	182.2A	7.2	178.0A	7.9	177.3A	6.6	168.5	7.6	29.0**
PALATWID	26.8A	1.6	26.7A	1.5	26.9A	1.7	26.9A	2.4	26.2A	1.6	26.4A	1.8	0.8
UPM2M3	79.2A	2.8	77.6A	3.5	78.9A	2.7	79.6A	3.7	79.1A	3.0	75.5	3.3	12.4**
LPM2M3	86.8B	3.2	86.6B	4.0	86.0A,B	3.5	85.7A,B	4.4	84.2A,B	2.9	83.5A	3.5	7.5**
M2M2	74.4B	2.2	74.5B	2.4	73.5A,B	2.7	73.3A,B	3.4	73.5A,B	2.5	72.4A	2.7	6.3**
DIASTEMA	72.7A	3.8	71.3A	4.5	73.8A	4.9	71.7A	4.9	70.0A,B	4.6	67.4B	4.6	12.6**
CRANBD	73.6A	2.5	74.3A	2.5	74.9A	2.8	72.7A	2.6	72.8A	1.8	73.1A	2.4	4.2**
CRANHT	68.3A	2.3	68.1A	3.1	68.3A	1.8	67.5A	3.0	67.2A	2.4	67.9A	2.3	0.8
INCISIVE	37.8A,B	3.4	37.9B	3.1	38.5A,B	2.6	39.1B	3.2	37.8A,B	4.2	36.0A	3.5	4.7**
POSTPAL	75.5A	3.7	75.8A,B	4.0	78.7A,B	5.1	77.4B	3.9	75.1A,B	3.8	75.6A	3.3	3.5*
CONDYLAR	48.9A	2.2	49.4A,B	2.1	50.7A,B	2.1	49.4B	2.6	47.4A,C	2.3	47.1C	2.2	15.4**
ROSTRAL	39.4A	2.3	39.5A	2.6	40.4A	2.0	38.0A	2.7	38.6A	2.9	38.9A	2.2	3.1
MANDLEN	221.4A,B	6.3	219.0A	7.3	224.8B	7.6	221.8A,B	9.0	216.5A,C	7.7	211.0C	7.6	21.7**
MANDHT	108.4A	4.5	105.6A,B	5.2	107.9A,B	4.9	106.2A,B	5.1	107.1A,B	7.1	103.8B	5.3	5.9**

*$P<0.01$, **$P<0.001$

*5,261-266 df

Fig. 1. Maps depicting currently accepted ranges of *Odocoileus virginianus borealis*, *O. v. macrourus*, and *O. v. virginianus* (TOP; dots represent collection localities) and collection localities within Illinois (BOTTOM).

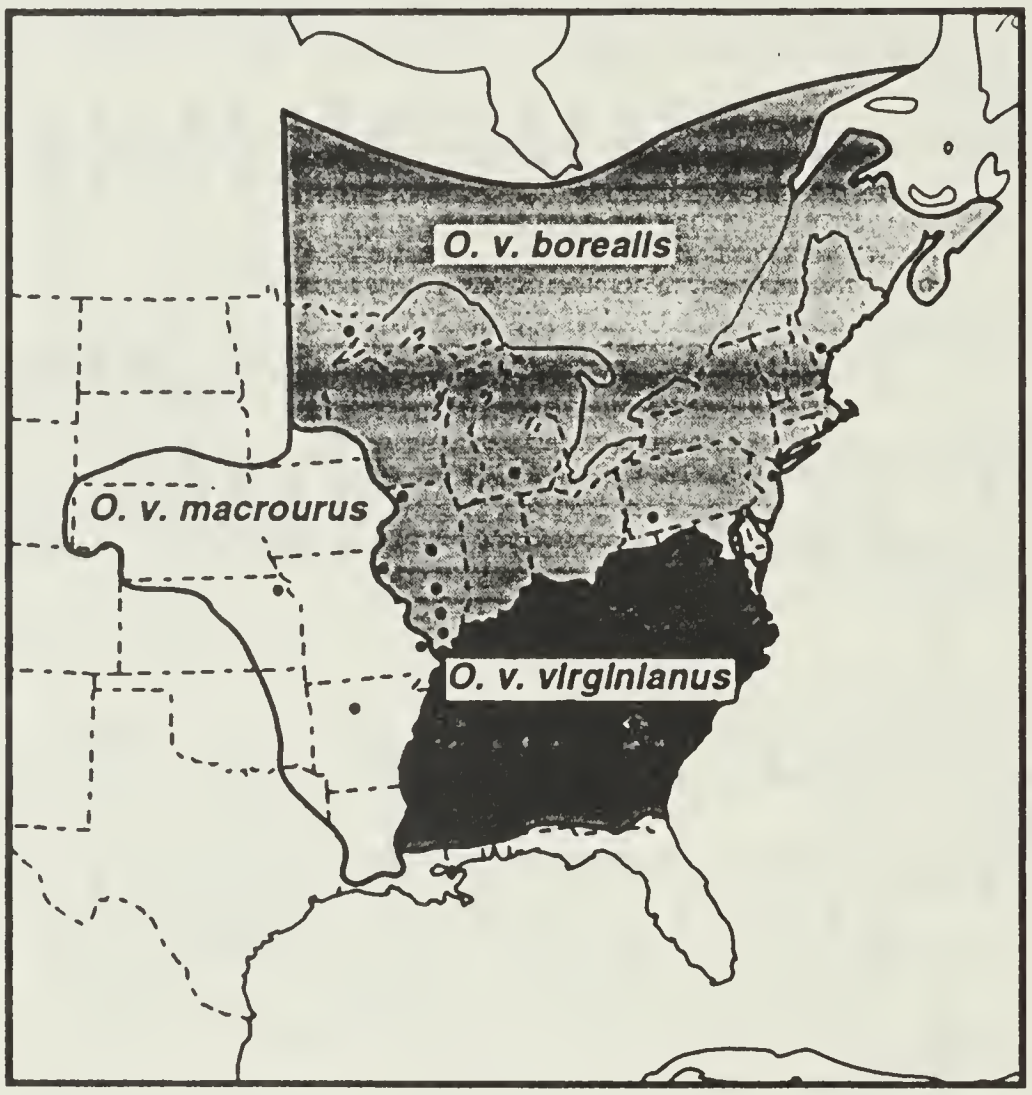


Fig. 2. Latitudinal variation in palatal length (Paletlen) of *Odocoileus virginianus* skulls from 6 regions of Illinois.

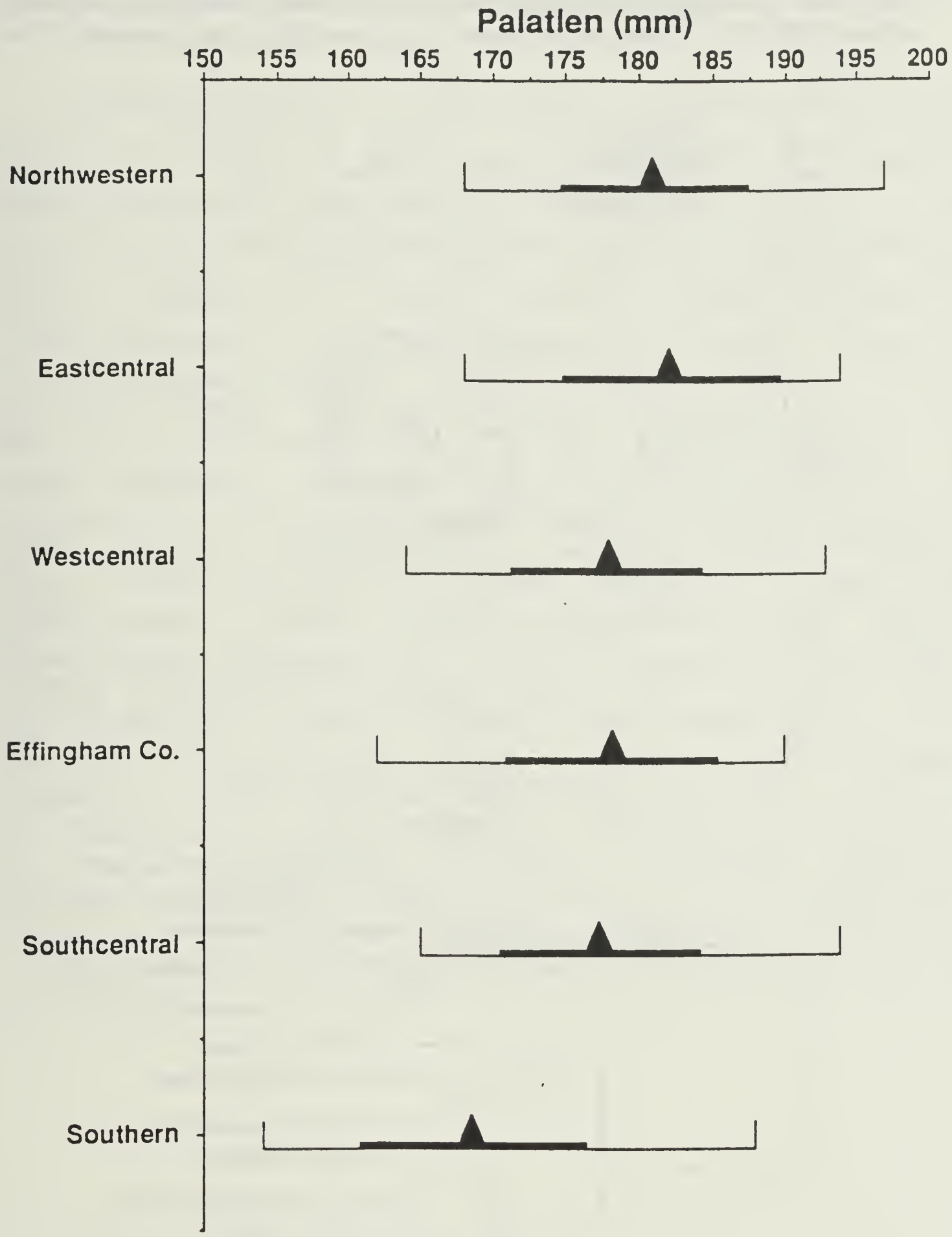
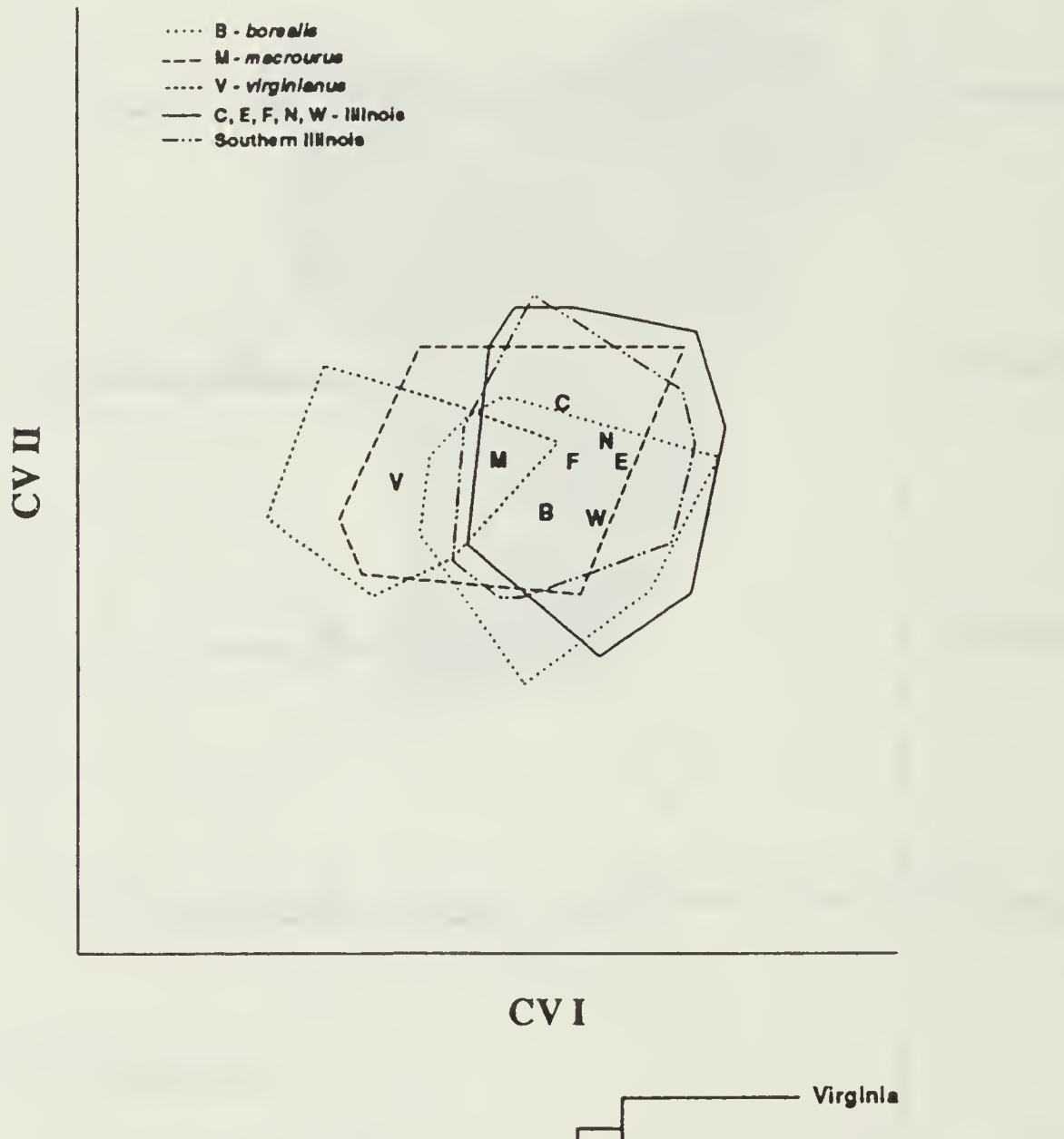
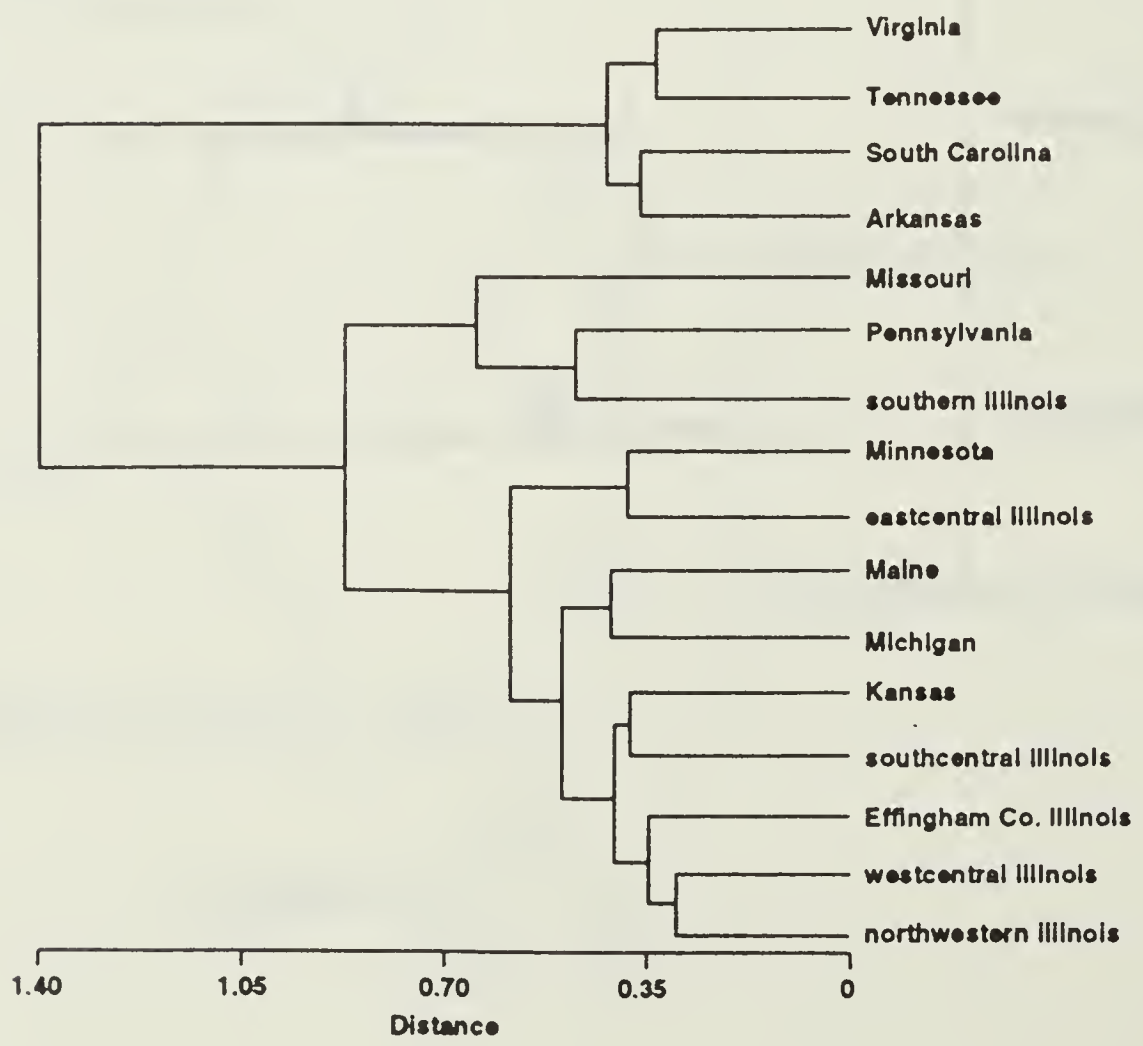


Fig. 3. Morphometric relationships among samples of *Odocoileus virginianus* from 16 localities within the eastern and midwestern United States: a (TOP) plot of canonical-variate scores based upon a series of 20 cranial measurements, and b (BOTTOM) phenogram of morphometric relationships based upon a cluster analysis (UPGMA) of standardized character means of 20 cranial characters.





APPENDIX I
Specimens Examined

Collection localities, number of specimens, and acronyms of museums housing specimens.

ARKANSAS: Drew Co., 1 (CWRL); Pope Co., Holla Bend NWR, 12 (CWRL); Prairie Co., 3 (CWRL); Van Buren Co., 1 (CWRL); unknown (previous counties or Franklin Co.), 2 (CWRL). ILLINOIS: Adams Co., 16 (CWRL); Adams or Pike Co., 30 (CWRL); Alexander Co., Horseshoe Lake Conservation Area, 14 (CWRL), Horseshoe Lake Conservation Area or Crab Orchard National Wildlife Refuge (Williamson Co.), 4 (CWRL); Carroll Co., 11 (CWRL), Carroll or JoDaviess Co., 4 (CWRL); Carroll, Jo Daviess, or Whiteside Co., 37 (CWRL); Dewitt Co., 3 (CWRL); Effingham Co., 19 (CWRL); Jefferson Co., 8 (CWRL); Jo Daviess Co., 10 (CWRL); Livingston Co., 4 (CWRL); Livingston, McLean, or Piatt Co., 11 (CWRL); McLean Co., 6 (CWRL); Piatt Co., 2 (CWRL); Pike Co., 25 (CWRL); Washington Co., 12 (CWRL); Williamson Co., Crab Orchard NWR, 56 (CWRL). KANSAS: Douglas Co., 1 (KU); Douglas, Jefferson, or Leavenworth Co., 24 (CWRL); Johnson Co., 1 (KU); Leavenworth Co., 3 (KU). MAINE: Androscoggin Co., 1 (CWRL); Kennebec Co., 2 (CWRL), Oaklawn, 1 (CWRL); Knox Co., Appleton, 1 (CWRL); Penobscot Co., Orono, 1 (CWRL); Somerset Co., 1 (CWRL); Waldo Co., 2 (CWRL), Belfast, 1 (CWRL), Brooks, 1; York Co., 3 (CWRL); southern Maine, 3 (CWRL). MICHIGAN: Clinton, Ingham, or Shawassee Co., 24 (CWRL); Livingston Co., George Reserve, 6 (UMMZ). MINNESOTA: Cook, Itasca, Lake, St. Louis C., 34 (CWRL). MISSOURI: Cape Girardeau Co., 27 (CWRL). PENNSYLVANIA: Westmorland Co., 9 (CMNH), Rachelwood Wildlife Research Preserve, 17 (CWRL). SOUTH CAROLINA: Aiken/Barnwell Cos., Savannah River Plant, 17 (CWRL). TENNESSEE: Carroll/Henderson Cos., Natchez Trace WMA, 1 (MSUMZ); Fayette/Hardeman Cos., Ames Plantation, 2 (MSUMZ); Hardeman Co., 3 (MSUMZ); Haywood Co., 1 (MSUMZ), Hatchie NWR, 11 (MSUMZ); Henderson Co., 1 (MSUMZ); Shelby Co., Shelby Forest WMA, 4 (MSUMZ). VIRGINIA: Allegheny Co., 1 (USNM); Bath Co., 1 (USNM); New Kent Co., 1 (USNM); Richmond Co., 1 (USNM); Shenandoah National Park, 1 (USNM).

Transactions of the Illinois State Academy of Science
(1994), Volume 87, 3 and 4, pp. 187-193

Notes on the Life History of Opossums in West-Central Illinois

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ABSTRACT

Opossums (*Didelphis virginiana*) were captured and marked in west-central Illinois from fall 1989 through fall 1993. Females predominated in spring and fall for birth year and after birth year captures. The highest minimum density was 7.7 opossums per 100 ha in spring 1993. Eighty-eight percent (N = 42) of after-birth year females were carrying pouched young when captured in the spring and averaged 9.9 ± 0.5 young. Annual survival of marked opossums was low on the study area, with only 5 of 182 (1 male, 4 females) recaptured 1 year after initial capture. Opossums were captured more often than expected in oak-hickory stands and old fields and less than expected in crop fields, assuming a opossum distribution similar to our trap distribution.

INTRODUCTION

The opossum is present throughout Illinois, and aspects of its life history have been reported from northwest (Verts 1963), east-central (Sanderson 1961, Holmes and Sanderson 1965), and southern (Stieglitz and Klimstra 1962) Illinois.

These notes on the life history attributes of the Virginia opossum in west-central Illinois were collected incidentally when investigating the ecology and life history of the raccoon (*Procyon lotor*) from fall 1989 through fall 1993. Our purpose was to provide some additional information concerning opossum life history in Illinois.

METHODS

We livetrapped opossums during fall (Aug-Oct) and spring (Apr-Jun) from fall 1989 to fall 1993. For fall 1989 and spring 1990, the study area included 3,222 ha of the Purpus and Wells Creek watersheds in Brown County, west-central Illinois. Subsequently, the study area comprised only the 2,310 ha within the Wells Creek watershed. These study areas averaged 59% agricultural fields, 23% oak-hickory woodland, 12% pasture, 4% shrub-old field, and 1% ponds; the remainder was in farmsteads (<1%) and Conservation Reserve lands.

Opossums were livetrapped using box traps baited with sardines (Sanderson 1961). Traps were not placed in a grid pattern but were placed in locations thought to maximize captures of raccoons. During each trapping period, trapping was begun at the north end of the watershed and progressively moved south along the watershed, with traps set in a given location for 2-5 days before being moved to a new site. This trapping pattern allowed us to trap throughout a large area but minimized recaptures of both species within trapping periods.

Captured opossums were sexed, aged as either birth year (BY) or after birth year (ABY), weighed to the nearest 0.1 kg, ear-tagged, examined for pouched young (if female), and released at the trap site.

Sex and age ratios were tested for differences using Chi-square analysis. Sex differences in body weights and movements between and within trapping periods were examined using 1-way ANOVA. Habitat preferences were determined with Chi-square analysis using total trap nights within each habitat as the proportion of each habitat available and the total captures within each type as the observed use of each habitat.

RESULTS AND DISCUSSION

Populations

Females predominated in our captures ($P<0.05$) (Table 1). Spring captures of ABY opossums averaged 68% female. Fall captures averaged 62% and 58% female for ABY and BY captures, respectively (Table 1). Based on other studies, livetrapped samples are biased toward females (Holmes and Sanderson 1965, Petrides 1949) whereas ratios derived from hunting and trapping are biased toward males (Reynolds 1945, Hamilton 1958). Females apparently are more susceptible to livetraps than are males (Holmes and Sanderson 1965, Blumenthal and Kirkland 1976). We sexed only a few young while they were still in the pouch (N = 26) and found nearly a 50:50 ratio (12 F:14 M). Pouched young averaged 51% male in New York (Hamilton 1958) and a 50:50 sex ratio for pouched young in east-central Illinois (Sanderson 1961) and south-central Pennsylvania (Blumenthal and Kirkland 1976).

The highest relative density of opossums (including young in the pouch) occurred in spring 1993, when 179 were captured on 2310 ha (7.7/100 ha). Seidensticker et al. (1987) estimated an average density of 3.9 opossums per 100 ha on a wooded site in Virginia. Other estimates have been 14 per 100 ha in New York (Van druff 1971), 13 per 100 ha in Kansas (Fitch and Sandidge 1953), 2 per 100 ha in Iowa (Wiseman and Hendrickson 1953), and 6 per 100 ha in Texas (Lay 1942). Holmes and Sanderson (1965),using after-weaning recoveries of young marked in the pouch, estimated between 223 and 634 opossums per mi^2 in east-central Illinois. These estimates may be inflated because of extensive dispersal from the study area by females with pouched young (Gillette 1980), but Holmes and Sanderson (1965) livetrapped up to 29 opossums per 100 ha. Our estimates of opossum densities were probably conservative compared to previous studies because other studies used higher trap densities set specifically for opossums.

Body Weights

In the fall, the average weight (mean ± S.E.) of ABY males (3.02 ± 0.11 kg, N = 43) was significantly greater (F = 7.07, df 1,78, P<0.01) than that of ABY females (2.6 ± 0.09 kg, N = 37). Males captured in the spring averaged 3.02 ± 0.15 kg. Female weights in the spring were biased by the presence of pouched young and were not indicative of female body mass. Male opossums are larger on average than females throughout their range (Hamilton 1958, Blumenthal and Kirkland 1976).

Reproduction

Spring breeding rates for ABY females averaged 88% (N = 42). Only 40% of the ABY females captured between late August and mid-October gave indication they had bred during the present year but fall examination is not a good indicator of the average breeding rate in opossums (Seidensticker et al. 1987). The breeding period extends from February through June in the Midwest (Petrides 1949, Reynolds 1945) with peaks in February and again in May because many females conceive 2 litters per year. Our trapping methodology did not provide data concerning the number of marked females conceiving multiple litters per year.

Pouched young were present with captured females from 10 April until 11 June. Twenty litters averaged 9.9 ± 0.5 young, with a range of 7 to 14, slightly larger than the 7.9 young per litter (N = 85 females) reported for east-central Illinois (Holmes and Sanderson (1965). Other average litter sizes reported include 8.9 in Missouri (Reynolds 1945), 8.6 in Nebraska (Reynolds 1952), 8.6 in New York (Hamilton 1958), and 8.2 in Oregon (Hopkins and Forbes 1979). Our recaptures were not frequent enough to estimate mortality rates for pouched young, reported to be <25% for most females (Llwellyn and Dale 1964, Sanderson 1961).

Recovery Rates

Recapture rates of marked opossums were low in west-central Illinois for both the fall-to-spring and spring-to-fall intervals. For the fall-to-spring period, we recaptured none of 43 BY males, 2 of 30 BY females (6.7%), 1 of 61 ABY males (1.6%), and 8 of 48 ABY females (16.7%). For the spring-to-fall interval for ABY opossums only, we recaptured 5 of 25 males (25%) and 11 of 54 females (29%). Only 5 of 182 marked opossums (1 male, 4 females, 1.6%) were captured 1 year after initial capture. Seidensticker et al.(1987) found the number of females livetrapped after their birth year was more constant than the number of males livetrapped after their birth year, which was indicative of a lower dispersal rate for females.

In Virginia, maximum longevity was only 28 and 24 months for females and males, respectively, and only 8% of marked females survived into a second breeding season at age 24 months (Seidensticker et al. 1987). In east-central Illinois, Holmes and Sanderson (1965) found that only 5.0% of adult opossums were recaptured the year after initial tagging. Van Druff (1971) estimated an average winter carryover of 9.2% in New York. Gillette (1980) found that no adults present on a Wisconsin study area in 1971 survived to breed in 1972. Llewellyn and Dale (1964) captured only 6 of 224 opossums (2.6%) 1 year or more after initial tagging in Maryland. Fitch and Sandidge (1953) recaptured only 4 of 106 tagged opossums the year following marking in Kansas. Verts (1963) found the

maximum elapsed time between the first and last capture for any individual opossum was only 80 days in northwest Illinois.

Petrides (1949) calculated an average life expectancy from birth of 1.3 years for the opossum, with a 4.8-year turnover in the population. Llewellyn and Dale (1964) argued that Petrides' estimates were too high.

Movements

Our limited trapping program was not designed to assess home range size or to monitor daily activity. However, recaptures of previously marked individuals provided some indication of movements within and between trapping periods. For BY opossums within a fall trapping period, male movements averaged 186 ± 32 m (N = 33) and female movements averaged 201 ± 40 m (N = 21) between recaptures (P>0.10). After birth-year male movements averaged 264 ± 51 m in the fall (N = 21) and 404 ± 207 m in the spring (N = 6)(P>0.10). After birth-year female movements averaged 345 ± 98 m (N = 33) in the fall and 269 ± 46 m in the spring (N = 30) (P>0.10). Movements between trapping periods were larger than within-period movements for both sexes. Fall-to-spring movements for juvenile females averaged 815 ± 356 m (N = 5); too few juvenile males were recaptured to estimate movements. For ABY opossums, male movements averaged 1,076 ± 247 m (N = 7) and female movements averaged 510 ± 251 m (N = 20) between recaptures in consecutive trapping periods (P>0.05). The longest known movement of a marked opossum was 5.2 km for an ABY female.

Opossums have been described as nomads with no fixed abode (Reynolds 1945). However, Gillette (1980) using radio marked individuals, found that home range boundaries were quite flexible, but that ABY opossums of both sexes remained within definable home ranges for months at a time. He also found that BY young gradually moved away from their mother after weaning and that dispersal movements stopped with the advent of cold weather (Gillette 1980).

Several studies have demonstrated that dispersal is extensive among both BY and ABY opossums during the growing season (Gillette 1980, Fitch and Shirer 1970). Apparently, females disperse with pouched young. Such movements facilitate repopulation of depleted habitats and may be a contributing factor in the recent northward extension of their continental range (Gillette 1980).

Holmes and Sanderson (1965) found the average movement between recaptures in successive nights to be 228 m for BY opossums, 88 m for ABY females, and 162 m for ABY males. Other studies found the mean distance between captures to be 527 m (Verts 1963), 403 m (Wiseman and Hendrickson 1950), 445 m (Lay 1942), and 249 m (Fitch and Sandidge 1953). However, unrestricted nocturnal movements may be considerably greater because Seidensticker et al. (1987) found that radio marked opossums moved an average of >1,100 m per night throughout the year in Virginia. Gillette (1980) also followed radio marked opossums in Wisconsin and found nightly foraging movements during nonwinter months to average 946 m for males and 413 m for females. After-birth-year home ranges averaged 108 ha for males and 451 ha for females (Gillette 1980). Ryser (1992) found that home ranges of male opossums in Florida overlapped 5-7 females and

that males regularly moved over a well-defined area checking on the reproductive status of these females.

Habitat

Because traps were set to maximize captures of raccoons, our opossum captures may not be a true reflection of habitat selection by Illinois opossums. In all overstory types, traps were generally set along waterways to capture raccoons so captures reflect relative use of waterways within each habitat type. We used trap nights (1 trap set for 1 night) per habitat type as a measure of habitat availability. We found growing season captures to be more common than expected in oak-hickory and old field habitats and less frequent than expected in croplands (Table 2). Reynolds (1945) found that opossums in Missouri favored mixed age class forest along small streams, similar to the habitat favored in west-central Illinois and considered water to be an essential component of opossum home ranges. Llewellyn and Dale (1964) reported that opossums in Maryland were found primarily in low, dense woodlands near water but avoided crop fields and dry upland woods.

CONCLUSIONS

As noted by Seidensticker et al. (1987), the opossum is about as far toward the r side of the r/K strategies of the survival continuum as mammalian morphology and physiology make possible. Observations in west-central Illinois are consistent with an r-selected life history strategy, e.g., a short gestation, large litters with minimal parental care, rapid onset of puberty in both sexes, and high mortality rates. Low survival and high dispersal rates are normal for this species, with populations dominated by individuals < 2 years old (Seidensticker et al. 1987, Llewellyn and Dale 1964) In west-central Illinois, as elsewhere, opossum numbers fluctuate annually on the basis of resource availability (Seidensticker et al. 1987). At present, human exploitation is not an important mortality factor because of low pelt prices.

ACKNOWLEDGMENTS

We thank the Brown County landowners who allowed us to trap on their farms. Drs. G.C. Sanderson , S. K. Robinson and the editorial office, Illinois Natural History Survey, reviewed the manuscript. This paper is a contribution (in part) of Federal Aid in Wildlife Restoration Project W-104-R, the Illinois Department of Conservation, the U.S. Fish and Wildlife Service, and the Illinois Natural History Survey, cooperating.

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Table 1. Sex and age of opossums captured in west-central Illinois 1989-93.

Season		Birth Year		After Birth Year		
		Male	Female	Male	Female	Total
Fall 1989		11	25	9	11	56
Spring 1990		--	–	5	11	16
Fall 1990		19	23	8	10	60
Spring 1991		--	–	4	8	12
Fall 1991		5	6	11	19	41
Spring 1992		--	–	3	18	21
Fall 1992		8	7	2	8	25
Spring 1993		--	–	13	17	30
Fall 1993		8	8	9	21	46
Total	Spring	--	–	25	54	79
	Fall	51	69	39	69	228

Table 2. Frequency of opossum captures during the growing season in west-central Illinois.

Habitat	Proportion Available[a]	Total Captures	Expected Captures	Chi-Square Values	P Values
Mature Oak Hickory	0.347	194	153	11.18	0.001
Crops	0.307	108	135	5.43	0.05
Pasture	0.103	34	45	2.83	NS[b]
Upland shrub	0.077	44	34	3.02	NS
Farmstead	0.054	19	24	0.9	NS
Ponds	0.034	11	15	1.1	NS
Successional Forest	0.027	7	12	2.0	NS
Old field	0.022	16	10	4.13	0.05
Grassland	0.011	1	5	3.05	NS
Fallow (CRP)[c]	0.009	4	4	0.002	NS

[a] Proportion of trap nights in each habitat.
[b] NS = Not significant.
[c] CRP = Conservation reserve program.

Transactions of the Illinois State Academy of Science
(1994), Volume 87, 3 and 4, pp. 195-200

The Distribution of the American Toad, *Bufo americanus* in North Central Effingham County, Illinois

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ABSTRACT

The American toad, *Bufo americanus*, is reported for the first time from 7 locations in Effingham County, Illinois. Choruses of this toad were heard only in the north central portion of the county. The apparent absence of choruses in the south central portion of Effingham County is consistent with previously published distributional maps for the species.

INTRODUCTION

Smith (1961) noted that the American toad, *Bufo americanus*, has been found over much of Illinois with the exception of a portion of southeastern Illinois that contain Wabash border forests and southern division forests (Fig. 1). Absence of the species from this region in Illinois and neighboring Indiana (Minton, 1972) results in a roughly circular gap toward the center of the range of the species (Smith, 1961, fig. 62).

Although Smith (1961, fig. 62) had no records of *B. americanus* from Fayette or Effingham counties, he suggested that its range included the portion of Fayette County west of the Kaskaskia River but not Effingham County. Tucker (1994) confirmed the occurrence of the species in Fayette County. During the springs of 1991 through 1993, I traveled many roads through the northern half of Effingham County in search of *B. americanus* choruses to delineate the limits of the species range in the northwestern corner of the range gap. The results of that survey are reported herein.

METHODS

Surveys for toads were conducted during the springs of 1991, 1992, and 1993. I surveyed by automobile. During 1991, I surveyed many areas by stopping the automobile and listening for calling toads. If chorus were heard, I attempted to locate them and capture individual specimens for positive identification. From the results of the 1991 survey, I selected 17 sites (Fig. 2) for continued monitoring during subsequent years. Ten of these sites were ones where *Bufo americanus* were found in the 1991 survey. I also selected seven sites where *B. americanus* choruses were not found for continued monitoring. These latter sites had habitat that appeared suitable to me for *B. americanus* and were geographically close to known breeding chorus of the toad. I visited each of the 17 sites

at least once each spring in 1992 and 1993 at times when *B. americanus* was calling at one or more of the sites.

RESULTS AND DISCUSSION

I found choruses at the following localities (Fig. 1): dam and Wren Drive area of Lake Sara, 4.3 km W of Effingham (INHS 10940); Little Wabash River at junction with Ford Avenue, County Road 1175E; Little Wabash River at junction with US Route 40; Shoal Creek, 0.9 km E of junction with Ill. Route 32; Shoal Creek at junction with Ill. Route 32 (INHS 10941-45); North Fork of Shoal Creek at junction with County Road 2000N; Green Creek, 0.2 km S of County Road 1800N; Green Creek at junction with County Road 1400E; and Lake Pauline, 0.7 km W of Effingham. Voucher specimens are deposited in the collections of the Illinois Natural History Survey (INHS). The toads that I report herein are identifiable as *B. a. americanus x charlesmithi* intergrades using the criteria defined by Smith (1961).

The habitat at each of these sites is similar. It consists of bodies of water (streams, rivers, lakes, and ephemeral ponds and puddles) in close association with outlier prairies (Smith, 1961; Vestal, 1931). At each of the ten sites with choruses of *B. americanus*, the toads were found calling in open woods or savannah settings. The prairies themselves have been converted to agriculture. Toads were also found crossing roads within agricultural areas but no choruses were found in open treeless areas.

Bufo americanus was absent from other creeks near the areas where I found it. Lack of chorusing toads indicates either that they are not present or that they are present but were missed. I believe it is more likely that the species does not occur in these adjacent areas because the sites were all visited at least once per year during three consecutive years and at times when the species was in chorus at the other Effingham County sites.

Sites where no choruses were found are: Lily Creek at junction with US Route 40, T7N, R5E, sec. 4; Altamont Reservoir near Big Creek; Second Creek at junction with County Road 650E; Salt Creek at junction with Crystal Club Road, County Road 1600E; Salt Creek at junction with County Road 500N; Little Wabash River at junction with Ill. Route 37; and Little Salt Creek at junction with Ill. Route 33. The habitat at each of these locations appeared to me to be similar to habitats at sites where *B. americanus* were found.

Although *B. americanus* certainly ranges into areas such as Effingham County, I cannot explain why the range does not include other seemingly suitable areas such as the Salt Creek and Little Salt Creek areas of Effingham County (Fig. 2). These creeks drain outlier prairies (*sensu* Smith, 1961) just as do all of the other streams along which choruses of *B. americanus* were found.

At present no cogent explanation exists to account for the gap in the range of *B. americanus*. The gap includes portions of Illinois, Indiana, and Kentucky (Conant and Collins, 1991). Before considering possible reasons for the gap, it is appropriate to review the systematics of *B. americanus* in this region. Smith (1961), Minton (1972), and Conant and Collins (1991) recognize two subspecies, *B. a. americanus* and *B. a.*

charlesmithi. The former race is a large toad (largest Illinois specimen 90 mm in snout vent length, Smith, 1961) whereas the latter is often referred to as the dwarf race (largest Illinois specimen 69 mm in snout vent length, Smith, 1961). Besides differences in size, these toads also differ in ventral coloration. Typical specimens of *B. a. americanus* have a moderately to heavily spotted or blotched ventral area whereas specimens of *B. a. charlesmithi* have the venter nearly spotless.

Toads identified as *B. a. americanus* (see Conant and Collins, 1991, for a recent survey) occur along the northern border of the range gap whereas the southern border is occupied by toads identifiable as *B. a. charlesmithi*. In Illinois, Smith (1961) restricted the range of *B. a. charlesmithi* to the Shawnee Hills Section and bordering Coastal Plain Province. He suggested that a broad intergrade zone was present between the two races in west central Illinois (Fig. 1). This intergrade zone falls in the Springfield Plain and a portion of the Mt. Vernon Hill Country (Smith, 1961). Smith (1961) restricted the range of typical *B. a. americanus* to areas of Illinois north and east of the Shelbyville Moraine and glacial plains such as the Galesburg Plain in western Illinois. The range gap itself in Illinois is coincident with the Mt. Vernon Hill Country of Smith (1961).

Each of these physiographic regions have broad characteristics that may have some implications concerning the range gap. The area occupied by *B. a. americanus* and *B. a. americanus x charlesmithi* hybrids is characterized by relatively little relief (with notable exceptions) and much of the presettlement vegetation was prairie or prairie dissected by gallery forests along the streams draining it particularly north and east of the Shelbyville Moraine. Border areas south and west of this moraine have more extensive development of forests but significant prairie outliers were present (Vestal, 1931; Smith, 1961). The area occupied by *B. a. charlesmithi* on the other hand is characterized by high relief (again with notable exceptions) and was mostly forested.

Previous attempts to explain the *B. americanus* range gap have suggested that competition with *B. woodhousei fowleri* (Minton, 1972) or that abiotic factors such as temperature and rainfall (Smith, 1961) may account for the range gap. Since *B. americanus* (both subspecies) and *B. w. fowleri* are widely sympatric in other areas of Illinois (Smith, 1961) and the United States (Conant and Collins, 1991), the first explanation seems to me to be unlikely. Furthermore, there is evidence (Brown, 1970) that both toads have adapted their body sizes in response to sympatry rather than one or the other being excluded. No studies have been published testing Smith's speculations of the importance of abiotic factors in the distributions of the two subspecies. Finally, Brown (1970) suggested that the hiatus was due to historical factors related to separation of the two races of *B. americanus* during the Pleistocene. This hypothesis is also untested. The cause of the range gap will remain unclear until further detailed studies of the distribution of the species in Illinois and Indiana are conducted.

ACKNOWLEDGMENTS

I thank L. E. Brown and D. Moll for reading the manuscript. M. M. Tucker helped collect toads at Lake Sara. The comments of one of the anonymous reviewers of this paper are gratefully acknowledged.

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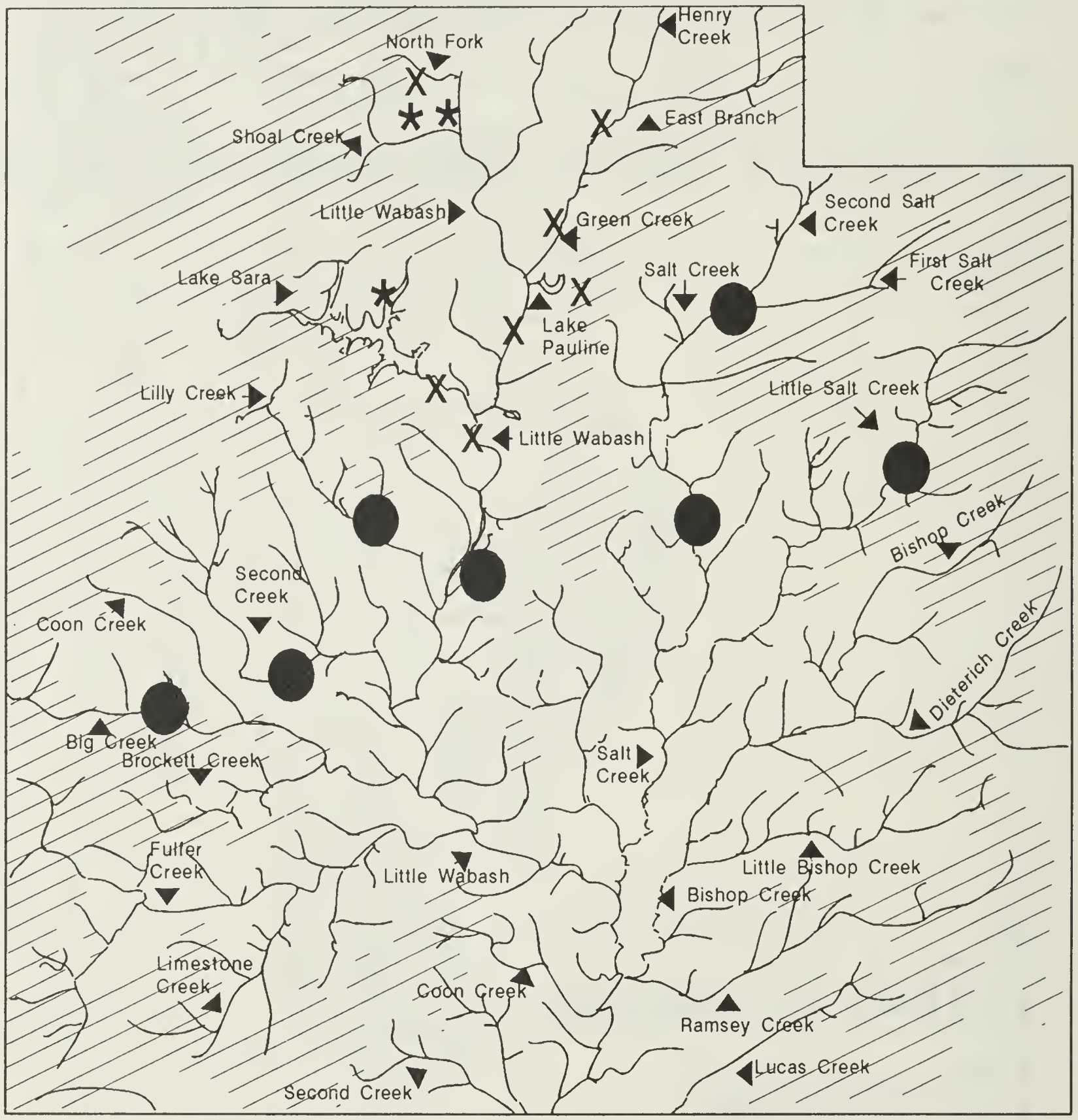
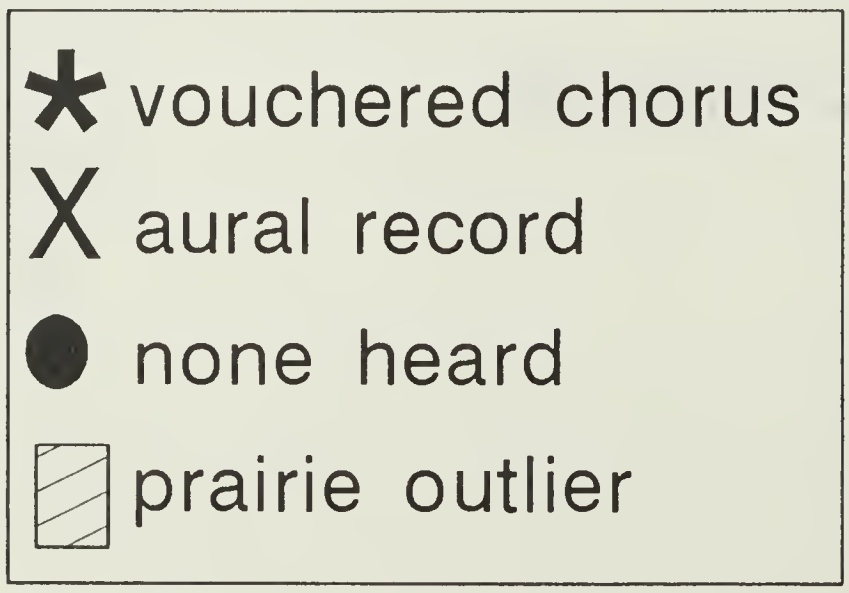
Figure 1. The distribution of *Bufo americanus* in Illinois. Stippling redrawn from Smith (1961, Fig. 62).

Figure 2. The distribution of *Bufo americanus* in Effingham County in relation to prairie outliers. Prairie outliers redrawn from Smith (1961, Fig. 4); Southern division forests predominate in areas without diagonal hatching.





Transactions of the Illinois State Academy of Science
(1994), Volume 87, 3 and 4, pp. 201-206

Two Further Specimens of the Three-Toed Box Turtle, *Terrapene carolina triunguis*, from Illinois and a Proposal for its Inclusion as a Member of the Herpetofauna of Illinois

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ABSTRACT

The three-toed box turtle, is reported for the first time from Madison and Union Counties, Illinois. Its nomenclatural status as a subspecies and the possibility that specimens were transported into Illinois are not sufficient reasons to exclude the taxon as a member of the Illinois herpetofauna. The turtle should be added to the list of Illinois reptiles and amphibians.

INTRODUCTION

Two species of box turtles, *Terrapene ornata* and *T. carolina* occur in the United States. *Terrapene carolina*, the subject of this report, ranges throughout central and eastern United States (Milstead, 1969; Ernst and Barbour, 1972) and is polytypic. Based primarily on analysis of various shell parameters and coloration of the carapace, Milstead (1969) recognized four subspecies, *T. c. carolina, T. c. bauri, T. c. major,* and *T. c. triunguis*. Intergrade zones between them were also suggested. We have redrafted Milstead's (1969, Fig. 1, p. 6) map by plotting the locations of samples he considered typical of one or the other of the subspecies with letter codes and by shading areas where he reported intergrade samples. The range limit on our map (Fig. 1A) is redrawn from Ernst and Barbour (1972). We also added a "C" for Illinois based on Smith's (1961) analysis of Illinois specimens of *T. carolina*. Our paper concentrates on the distribution of the subspecies *T. c. carolina* and *T. c. triunguis*.

Only *T. c. carolina* occurs in Illinois, which is the western extreme range of the subspecies (Fig. 1A). However, the situation is more complex. Smith (1961) reported the first documented specimen of *T. c. triunguis* in Illinois from Calhoun County which he dismissed as an extralimital waif. Morris et al. (1983) also excluded the subspecies from their checklist of reptiles and amphibians of the state. No further specimens were reported from southern Illinois until Paukstis and Janzen (1988) reported a specimen from Alexander County. This report was followed shortly by notes on specimens published by

Gilbert and Gilbert (1992), Paukstis and Janzen (1993), and the current report. Thus between 1961 and 1988 a single specimen had been reported whereas 5 have been found between 1988 and the date of this report. This sudden increase in reports for southern Illinois could be due to the recent arrival of the turtle in the area. Also the 1988 report of Paukstis and Janzen (1988) may have stimulated herpetologists to report specimens that would have otherwise been dismissed as escapees or waifs. This was suggested by Morris' mention (to Paukstis and Janzen, 1988, p. 284) of other specimens collected in the state that went unreported. The purpose of our paper is to report two further specimens of *T. c. triunguis* from Illinois and to argue that there is now good reason to consider this turtle a resident of Illinois.

MATERIAL

The turtle from Madison County was found June 20, 1993, crossing New Poag Road, 1 km E of its junction with the Norfolk and Western railroad in T4N, R9W, NE1/4 NE1/4, sec. 13. The plastron of this female measured 139.7 mm in length. The left hind feet possessed three toes. The right hind foot had 4 with the fourth toe being very small but with a distinct nail at its end. The carapace was a nearly uniform horn coloration (*sensu* Milstead, 1969, p. 56). The plastron was without dark markings. The specimen was deposited in the collection of the Illinois Natural History Survey (INHS 10980). The Union County specimen was found May 23, 1993, on forest road 345 0.8 km E of Illinois Route 3 in T11S, R3W, SW1/4 SW1/4 sec. 21. The specimen, an adult male, was not measured. It was photographed (Fig. 2) and released at the collecting site. It, too, was horn colored but has slight development of yellow radiating lines at the centers of the carapacial scutes. Each hind foot had three toes.

DISCUSSION

Turtles possessing morphological traits identifying the subspecies *T. c. triunguis* have not previously been reported from Madison or Union Counties in Illinois. Paukstis and Janzen (1993) mention a specimen from Union County but this is a lapsus for the specimen reported previously by them (Paukstis and Janzen, 1988) from Alexander County (G. L. Paukstis, pers. comm.).

Paukstis and Janzen (1993) discussed the status of *T. c. triunguis* in Illinois and only tentatively concluded that it was established in the State. They attributed its presence in Illinois to natural means of transport from neighboring Missouri though they noted human transport can never be excluded from consideration. Yet, their report "...does not prove that *T. c. triunguis* in now established in Illinois." (Paukstis and Janzen, 1993, p. 175). We, however, interpret these findings differently.

Compared to previous reports on Illinois' turtles, we suggest the following terminology. We prefer the terms "resident" or "introduced" rather than "native" or "established". Established implies a recent event whereas native implies a long history of occurrence in the geographic area under consideration or at least occurrence prior to the arrival of a second entity. When the observer is not present at the initial colonization or subsequent recolonization event or events, then it is difficult to decide whether something not previously reported in the literature is a rare or overlooked "native" or is newly

"established". We propose the term "introduced" be used only where it is known, through historical documentation or very strong evidence, that the organism was transported to the location by humans. The term "resident" is better for those taxa not considered "introduced" than is the term "native", because it carries no relational component. A separate determination is necessary to decide how long a resident taxon has been at the location where it was recently discovered, how it got there, and its biological status.

Terrapene c. triunguis has been considered recently introduced into Illinois (or more commonly as an exotic waif) because it is relatively rare compared to *T. c. carolina*; because box turtles are kept as pets and specimens could be escaped pets; or because it is much more common in areas bordering Illinois than it is in Illinois. We believe these circumstances apply equally well to a number of amphibians and reptiles inhabiting Illinois. Smith (1961) reported several species for which five or fewer records were documented by specimens. With the exception of *Tropidoclonion lineatum*, a small fossorial and highly secretive snake, all of these species share one of two kinds of distribution patterns. They are either restricted to large rivers (3 species) or are found along one of the borders of the state (15 species). The occurrence *T. c. triunguis* appears comparable to the species reported by Smith (1961). Like *T. c. triunguis*, these species are all much better known and more common from areas bordering Illinois than they are in Illinois. At least some (*Hyla cinerea, Clemmys guttata, Pseudemys concinna, and Elaphe guttata*) are kept as pets. Therefore, it is inconsistent to use any of these three factors as valid reasons to consider specimens of *T. c. triunguis* nothing more than waifs while including the other 18 taxa as residents of Illinois. Of course, some reports of extralimital specimens of *T. c. triunguis* are very likely the result of escaped pets such as reports for northern Illinois (Dancik, 1974; Ludwig et al., 1992) and for Guam (McCoid, 1992; 1993). These reports differ from those for southern Illinois since they are not geographically close to the accepted range of *T. c. triunguis*. The two specimens we report are important because they fill gaps between the Calhoun County record and those reported for other counties (Fig. 1B).We agree with Paukstis and Janzen's (1993) conclusion that *T. c. triunguis* is resident. Therefore, we believe that it should be listed in the herpetofauna of Illinois.

ACKNOWLEDGMENTS

We thank Chris Phillips and Gary Paukstis for helpful comments on the manuscript. James B. Camerer made the print for figure 2. This work was partially supported by the Illinois Natural History Survey and the Upper Mississippi River System Long Term Resource Monitoring Program.

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Fig. 1. **A**: Distribution of the subspecies of *Terrapene carolina* (letter codes) and their intergrade zones (cross hatching) in the United States. Letter codes and cross hatching based on Milstead (1969, Fig. 1, p. 6) for all but Illinois (Smith, 1961). Limits of range redrawn from Ernst and Barbour (1972).
B: Locations of specimens of *Terrapene carolina triunguis* in southern Illinois. Records reported by Paukstis and Janzen, 1993 (A), Gilbert and Gilbert, 1992 (B), Paukstis and Janzen, 1988 (C), Smith, 1961 (D), and this study (E and F).

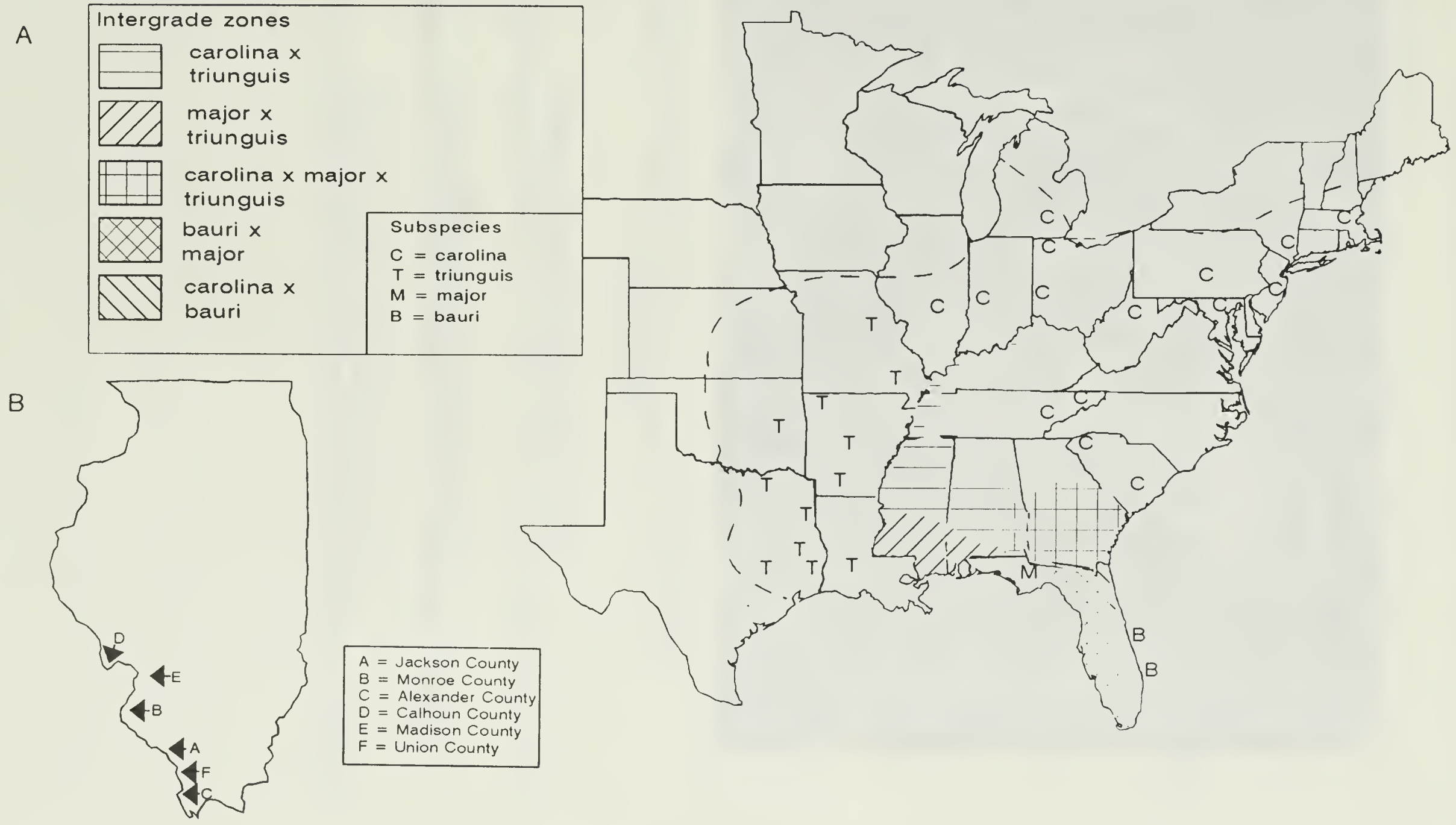

Fig. 2. Male specimen of *Terrapene carolina triunguis* from Union County, Illinois.

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Transactions of the Illinois State Academy of Science
Volume 87 (1994)

CONTENTS

Academy of Science Editorial Information ..... inside front cover

Botany Papers

Greenberg, Joel and Margo R. Milde
The Occurrence of Four Rare Plants in Cook County 113

Nelson, John C., Anjela Redmond, and Richard E. Sparks
Impacts of Settlement on Floodplain Vegetation at the Confluence of the Illinois and Mississippi Rivers 117

Schanzle, Robert W. and Glen W. Kruse
A Survey of the Freshwater Mussels (Bivalvia: Unionidae) of the Green River Basin, Illinois 135

Zoology Papers

Baker, Steve C. and Roy C. Heidinger
Individual and Relative Fecundity of Black Crappie (*Pomoxis nigromaculatus*) in Baldwin Cooling Pond 145

Bavetz, Mark
Geographic Variation, Status, and Distribution of Kirtland's Snake (*Clonophis kirtlandii* Kennicott) in Illinois 151

Birch, Gary L., George A. Feldhamer, and William G. Dyer
Helminths of the Gastrointestinal Tract of Raccoons in Southern Illinois with Management Implications of *Baylisascaris procyonis* Occurrence 165

Goodrich, Michael A.
Microsternus ulkei (Crotch) (Coleoptera: Erotylidae), A Western Extension of its Range and First Record from Illinois 171

Levengood, Jeffrey M., Alan Woolf, and John L. Roseberry
Morphological Variation in White-Tailed Deer from Illinois 175

Nixon, Charles M., Joseph B. Sullivan, Terry Esker, and Robert Koerkenmeier
Notes of the Life History of Opossums in West-Central Illinois 187

Tucker, John K.
The Distribution of the American Toad, *Bufo americanus* in North Central Effingham County, Illinois 195

Tucker, John K. and James B. Hatcher
Two Further Specimens of the Three-Toed Box Turtle, *Terrapene carolina triunguis*, from Illinois and a Proposal for its Inclusion as a Member of the Herpetofauna of Illinois 201

Academy Notes 207

Contributor Information ..... inside back cover